SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

RESEARCH[1]

THE university is the natural home for research. The development of research institutes, except of those that have been built up around a great genius, and during the period of the active life of such a man, is apt, in the long run, to be more of a menace than help to the work of investigation. In a way the establishment of these institutes is a measure of university inefficiency. They mean that the universities have failed to rise to their full possibilities as centers of mental activity.

Research institutes lack the current of successive generations of students from which to pick out the right minds and to draw new blood. They do not feel the internal heave and struggle, the pressure that comes from association with the great turbulent mental forces that accompany youth. There is too much pressure for evident results, too much discipline of research minds to achieve a big effect. Just at the period when those who have the proper training and ability and the love for investigation that must go with success in discovering new things, many of the workers in research institutes and departments are compelled to work on the problems of some one else. This is valuable and satisfactory up to a certain point, but beyond that it means sterilization of the best that is in the men; it means putting aside their own projects, perhaps permanently. It is a serious thing for any one full of expanding ideas to be made a "scientific bootblack."

The university, if manned as it should

[1] Address before the Society of Sigma Xi at Stanford University, May 8, 1916.

be, is the ideal place for the development of fundamental research as contrasted with the more showy kind. If the tendency to forced stimulation of mediocre men, who have persistence and the leisure that may come from fellowships and scholarships, can be minimized, the universities can and eventually will become the seat of the greatest ferment, working out toward new discoveries.

Our whole concept of education has changed. It is now one of fact and not opinion. The "theological period" of assertion has largely gone by. There is no common source of information, no palladium such as the Bible is to religion, in modern science. What Agassiz says has no final value except to those who know his record, his trained mental processes, his method of arriving at pronouncements. We ask for foundations; we want to be able to see affirmation built up stone by stone; or we want to be able to work backwards and tear down the separate blocks, testing each and finding out thereby the real quality of the structure of assertions and theories formed by them. Allegiance to truth, as far as we can understand or discover the truth, is the main concern of the scientific worker of to-day. He knows that he must get into harmony with facts if his work is to be effective, to endure. Along with this appreciation of truth there has been a striking development of the conscience of the expert, who can only be partisan to the truth. The rescue of the so-called "expert" from his present unsavory position seems likly to follow the great advance in knowledge which has come from careful "fact study." We owe much of this very desirable change to the important body of information which has been brought together by those engaged in what we sometimes rather glibly call "research."

Research means a point of view, a type of mind, a healthy curiosity. It results in a welling up of inspiration. Our senses become blunt, our edges dulled to the usual, the old, the stereotyped. They keep acute to the new, the unexpected, the obscure, the intangible, the will-o'-the-wisp. For the interpretation of a subject to advanced students, only the mind alert in research, curious for the new, can be of the best service. Without that open point of view the solidification that usually begins in the early thirties of life soon becomes petrifaction. A noble mind has found its limits and will gradually wear off all its new contacts and beat its life out, leaving only the revolution of the treadmill to furnish evidence of activity. Freshened by contact with the new, the yet unexplained, the human intellect expands throughout life, becoming, through its constantly increasing store of fact and experience, more and more serviceable. Particularly is this true where the judgment has been developed through guiding others along the old paths and starting them off with compass and necessary equipment along the new paths which lead out to the maze and appealing mystery of the unknown.

The college or university teacher who fails to take a part in research in some form or another prunes himself of those branches that give promise of the best future fruit. There are many ways in which the research point of view may be maintained. It does not necessarily mean published work. It may be most serviceable to the teacher and yet show only in fresh thoughts, new stimulation to the student to think for himself, to investigate. It may be concerned largely with improvement in the presentation of subjects before classes. The man who devotes much of his time to research and experimental work and yet drags out the well-thumbed notes of bygone lectures to hammer at his classes is far from having the

research mind we need in the teacher. Such a man is of less value than the instructor who studies his subject but makes no pretense to so-called "productive work."

The research mind keeps up to date in its correlations and brings the inspiration of the best and newest into each teaching day. Sometimes one feels that the external drive towards research by university sentiment leads to many puny efforts and to abortive results. Perhaps, however, even though the result to science is small, the effect upon the individual is salutary. The greatest sport the world knows is the search for the absolutely new in any line. One need only sense the joy once to feel its lure.

I recall when working in Ehrlich's laboratory in Frankfurt his pleasure in each of the new chemical substances formed by him. He would make a new combination and show it to those working near him, even insist upon putting it into their hands to hold for a moment, saying: "Sehen Sie mal, jemand hat, es nie vorher gesehen; es ist ganz neu." Think of the satisfaction, the sport: "No one has ever seen it before; it is absolutely new." Who that could would not try a round in such a game? The successful players in it are those who have builded strong in mind and body—who have climbed to the upper heights, obscured by the mists, where the game is played. Each group of workers pushes the altitude upwards, broadens and solidifies the base, turns peaks into plateaus. The chosen few scale the lofty, unexplored spurs; the many join in filling in the gaps, opening up the intervening spaces, and making the secure level ground. We can not all be scouts; most of us must make up the rank and file of the army; some of us can only play the part of quartermasters.

The attitude of the university towards research should be a sane one. At times waves of research hysteria have swept over university circles and the sense of proportion has been lost. The number of published pages has seemed to be the standard of scholarship rather than the character of the work done. One has often seen research notes elaborated into articles; articles subsequently enlarged to monographs, and monographs padded out into books. The essential thing, however, is the discovered fact, the reasoning leading up to and away from the new fixed point. There is no common standard possible in this work nor in research in general; but the university can insist that the instruction offered by its research workers shall show that fresh and stimulating point of view, and that enthusiasm, that go with the growing mind that is abreast of the best thought in its subject. Under these conditions research will play that large part in the life of the university faculty which it should play, and students and teachers will make progress in their chosen fields.

Immortality is a theme upon which human thought has exhausted itself without absolute and universal conviction because it takes the human mind beyond its depth at the first long stride forward. But there is one phase of immortality about which we can all be assured. The mind of to-day can through the minds of to-morrow project itself into immortality. Ideas and ideals travel through generations of minds to eternity. It will ever be the inspiration of the teacher that to him in particular comes this great opportunity to be a part of the future, by moulding and guiding and training the minds of the present.

The man who discovers some new arrangement of forces, some new fact in regard to chromosomes, some fresh chemical combination, the cause of an obscure disease, has thereby become immortal, for his effort has added something which, if true, can not be lost to the human race. What

happier form of immortality than this—to have added something to the world's store of fact and of law!

Many then are the inspirations of research, and many the satisfactions of the teacher and the investigator. If we keep our view point clear, recognize the many ways in which new facts and new thoughts are garnered, avoid the spirit of pride and intolerance—we can be assured that from our university faculties there will come a spirit of research and of helpfulness that will act as a powerful factor in moving civilization onward and we hope upward.

RAY LYMAN WILBUR
STANFORD UNIVERSITY

CONTRIBUTIONS OF THE UNITED STATES COAST AND GEODETIC SURVEY TO GEODESY[1]

IN the earlier days of the Coast Survey, whose centennial is now being commemorated, the geodetic function, as such, was little in evidence. It was then simply an aid in carrying on the work outlined in the Act of 1807, which provided for a survey of the coasts of the United States, in order to provide accurate charts of every part of the coast and adjacent waters.

Upon the reorganization of the Survey in 1843, the cornerstone was laid for that fine system of geodetic works which the Survey has at present. In this reorganization two very prominent features, from a geodetic standpoint, are to be noted. The first is the man who was the dominant figure in the board of reorganization, and the second is the principles he advocated. Probably no other man has had the influence upon the geodetic operations of the Survey as had Superintendent F. R. Hassler, and probably no one thing has been of such importance to these operations as the scientific methods proposed by him. To him belongs the credit that to-day the operations of the Survey are bound together by a trigonometric survey with long lines, and executed by the most accurate instruments, and the most refined methods, rather than being correlated by purely astronomical observations. Due to his far-sightedness, the best of foundations was thus laid for geodetic operations, and from this time geodesy became an important part of the Survey's work.

A further impetus was given to the work when, shortly after the close of the Civil War, Congress authorized a geodetic connection between the Atlantic and Pacific coasts of the United States. The result of this was the great transcontinental arc of triangulation along the 39th parallel of latitude, one of the most famous arcs in the history of geodesy, and one which has helped to place the United States in the front rank of the nations carrying on geodetic operations. One of the immediate results was the recognition of the geodetic function as an important part of the Coast Survey's work, and in 1879 the Survey's title officially became "The Coast and Geodetic Survey."

THE TRANSCONTINENTAL ARC

The great triangulation system along the 39th parallel was probably the greatest single contribution to the world's geodesy that had been made by any one country. It marks an epoch in the scientific history of the United States and in that of the world. The results of the work are most important and far-reaching to geodesy, geography, geology, and the other earth sciences.

It is the longest arc of a parallel ever undertaken by a single nation, being more than 48° of longitude between its extremities, or about one-eighth of the earth's circuit, and is more than half the length of the combined arcs (measured by various

[1] Address given at the celebration of the centennial of the U. S. Coast and Geodetic Survey.

nations), used by Clarke in deriving the figure of the earth in 1880.

The nature of the country traversed by the arc developed new ideas in reconnoissance, signal building, triangulation and methods of computing, which have had an important bearing on all subsequent work. By means of it unity and consistency have been secured in the geodetic work of the Survey. It has proved a bond between the many separate parts of the Survey's work. These, at first, existed as a number of detached portions, in each of which the datum was necessarily dependent upon the astronomic observations. The transcontinental triangulations joined these detached portions and made them into one continuous system dependent upon the same geodetic and astronomic data.

From a higher scientific standpoint this arc is a great contribution to geodesy in giving data for the determination of the earth's shape and size, but like any other arc of a parallel, it must be combined with an arc in the north and south direction to obtain its full power in this respect.

THE EASTERN OBLIQUE ARC

In the Eastern Oblique arc the United States has another arc of note, which covers some 22°, and extends from the Bay of Fundy to the Gulf of Mexico at New Orleans. This was the direct result of Hassler's plans, was the scene of his last labors, and had for its main object the binding together of the detached surveys of the harbors of the Atlantic Coast.

Unlike the transcontinental arc, it has all the elements necessary for the determination of the figure of the earth. It is the first arc which made use, on a large scale, of measurements oblique to the meridian. One of its great effects on the geodesy of the United States was that, through it, came the rejection in 1880 of Bessel's spheroid of reference, and the adoption of the Clarke spheroid of 1866 as the reference spheroid to be used in this country.

ASSISTANT CHARLES A. SCHOTT

Many men took part in furnishing the data for these two arcs, and in the resulting computations, but no name stands forth so prominently as that of Assistant Charles A. Schott, the "Grand Old Man," who for more than fifty years was identified with the work of the Survey. His labors in the field and office did much to bring this work to a most successful finish, and it is fitting that credit be given him for the two monumental volumes of results which it was his privilege to see completed before death came. For this work, and for the work done in many other lines of the Survey's activities, I do not hesitate to mention the work of Mr. Schott as one of the great contributions made by the Coast and Geodetic Survey to the geodesy of the world.

The Survey was particularly fortunate in having such a man in charge of geodetic work; one who could see the full wisdom in the plans of Mr. Hassler, who consistently worked for their fulfilment, and who was able to have these plans transmitted to his successors, Assistant John F. Hayford and Assistant William Bowie. This furnished a continuity of plan which probably stands unrivaled in the scientific history of the world, and has been one of the big factors in the great success attendant upon the geodetic operations of the Survey.

RECENT TRIANGULATION

Since the completion of the arcs mentioned, the Coast and Geodetic Survey has added many more arcs to its system, until the total length of the combined arcs is more than 150° of a great circle of the earth, or about three sevenths of the circuit of the globe. Incorporated into the system

and placed on one datum are also the many miles of coast triangulation of the Survey and much of the triangulation executed by the Lake Survey and by the U. S. Engineers, until now the system stands without an equal in any nation.

In the closing years of the last century a new era in geodetic operations by the Coast and Geodetic Survey was begun. The work of the past was searched for the best in instruments and methods, field and office methods were standardized, limits of accuracy were set, and where it seemed advisable new methods and instruments were devised to meet the changing conditions of the work. This era may be characterized as a period of great speed and low costs.

Never before had triangulation been executed with such rapidity and with such economy in operations. It is significant that this was attained without a reduction in accuracy, and in fact had the effect of an ultimate increase in accuracy, for, owing to the speed, many more circuits could be added to the network, thus strengthening the whole system.

As an example of the speed and economy of operation in this last period the Texas-California arc of about 20° is cited. The reconnoissance on this arc was done by two men in 145 days and the primary observations in a total of 183 days at a cost of $400 per station and of $32 per mile of progress. Nearly 50 years were spent on the transcontinental arc of 48° with a cost of $2000 per station and $200 per mile of progress. This comparison is not intended to be derogatory to the latter arc, for the work on that arc was the best of any up to that date, and it was only through its work that the economy and speed of the later work was made possible. It is believed that no extensive arc in any other country equals the Texas-California arc or some of the other recent arcs of the United States, in these respects.

Since about 1900, practically all of the reconnoissance and signal building has been in the hands of one man, Signalman Jasper S. Bilby, who as an expert along these lines probably stands unrivaled in the world to-day.

THE UNITED STATES STANDARD DATUM

A direct and far-reaching geodetic movement of influence, not only to the United States, but also one of great importance to the North American continent, and also to the whole world, was initiated in the adoption by the Survey (in 1901) of the United States Standard Datum. It placed the geodetic work of the Survey on one datum for the correct coordination of the geographic latitudes, longitudes, distances and azimuths. From the scientist's standpoint it furnished accurate correlation of data for a study of the figure of the earth, of isostasy, and for other related sciences.

By its adoption, as the Standard Datum for geodetic operations in Canada and Mexico, it became a matter of international importance and consequently its designation was changed by the Survey in 1913 to that of the "North American Datum." Plans are now under way for carrying the primary triangulation of the United States and Canada to the Yukon, and the prediction is here made, that eventually the fifty miles which separate Alaska from Siberia will be spanned, and a junction be effected with the great systems of Asia, Europe and Africa. Then with the extension from Mexico through Central and South America, the data will be available for a "World Datum," and the final word will have been said in the geodetic work of the earth.

BASE LINE MEASUREMENTS

Closely related to, and forming an integral part of the triangulation executed by the Coast and Geodetic Survey, is the meas-

urement of the base lines for controlling the lengths in triangulation. In this work the Survey has furnished much of interest and of value to the geodesist. Ever has it kept keenly before it the necessity for refined measurements, and many valuable devices to accomplish this desired result have been added by members of the force.

BASE BARS

The Duplex bars, invented by Assistant William Eimbeck, are probably the best form of base bars ever devised and gave a very high degree of precision. But they were soon replaced by the tape as a form of base apparatus.

The only bar used in the United States, and probably in the world, which gives entire satisfaction, so far as accuracy is concerned, is the iced bar, designed by President R. S. Woodward of the Carnegie Institution when an assistant in the Survey. Owing to the great cost per kilometer of base of using this form of apparatus for field work, when compared with the cost of using tapes, the iced bar is now used only for standardizing other apparatus, and for this purpose it remains unexcelled.

STEEL TAPES

In the Coast and Geodetic Survey the tape has supplanted the other forms of base apparatus. Credit for the introduction of steel wires and tapes for this purpose must be given to Professor Jaderin of Sweden, but it was the accurate and extensive investigations made by Assistant Woodward in 1891 which caused the adoption of tapes by the Survey. He proved that steel tapes, when used at night, and standardized under the same conditions that prevail during the base measures, gave essentially the same high degree of accuracy as the Duplex bars, with about one third of the cost and with far greater rapidity. It is practically certain that no more base lines will be measured by base bars, at least in the United States, except when it is necessary to standardize the tapes.

The remarkable measurement of nine base lines in one season, in 1900, by a single party constitutes a noteworthy achievement. The nine bases had a total length of 43 miles and furnished a control of over 1,000 miles of triangulation. In order to eliminate constant errors five different sets of apparatus were used, and an average accuracy corresponding to a probable error of 1 part in 1,200,000 was secured. With this work a new epoch in base line measurement was introduced, for it proved, through the most rigid of tests, that the tape had no superior for speed, economy and ease of manipulation.

INVAR TAPES

In the use of invar tapes, base measuring took another long step forward. Many severe tests have fully proved their excellence. They are found to possess practically all of the good features of the steel tapes, but have the added advantage that they enable bases to be measured in the daytime and even in the sunny days, a fact due to the small coefficient of expansion of invar, which is only about one thirtieth that of the steel tapes.

Recently the plan has been adopted of having the bases measured by the triangulation party. By it base measurement has become simply an incident to the triangulation, and the cost has been reduced to about $60 per kilometer, a sum which is in great contrast to about $300 per kilometer with the Duplex bars.

PRECISE LEVELING

Practically all of the great nations of the earth have been actively engaged upon the difficult problem of determining the cor-

rect elevation of points far from their coast. It is a work which demands the highest degree of accurate observing and painstaking endeavor. It calls for especially designed instruments and methods of observation. These accurate elevations are needed for the reduction of base lines to mean sea-level, for engineering operations of wide extent, and for the solution of scientific problems concerning gravity, the tides and other work.

In this leveling of precision, the Coast and Geodetic Survey has added much to the world's work by attainments in field operations, methods of reduction and scientific study of errors involved. In its great precise level net (greater than that of any other nation) there are more than 15,000 bench marks, of which the elevations have all been accurately fixed through a single least square adjustment of more than 80 circuits with a total length of more than 25,000 miles.

THE COAST SURVEY LEVEL

Among the instruments of precision employed by the nations for precise level work, it may be truly said that none holds a higher rank than the type which has been in use in the Coast and Geodetic Survey since 1900. This level was designed and built within the Survey, and after more than fifteen years of constant service, in all parts of the United States, has shown itself to be indeed a superior instrument for accurate and rapid leveling.

Before the introduction of this level, the average rate of progress was less than 60 miles a month. Recent work, which is of much higher grade of accuracy, shows an average of nearly 80 miles; and one observer with a party of six men, last season completed 120 miles of progress, or more than 250 miles of single line in one month, which constitutes a world record.

Although precise leveling has been brought to the highest perfection in France, the Coast and Geodetic Survey, by the very magnitude of its operations, by the instruments employed, and by the economy in speed and cost, is certainly without an equal in the geodetic world.

ASTRONOMIC DETERMINATIONS

Considering astronomy as a definite part of its geodetic function, the Survey has added to the work done by the various nations many hundreds of astronomic latitude, longitude and azimuth determinations, mostly at stations connected directly with the great triangulation system. While no great changes have been introduced in latitude and azimuth work as far as instruments are concerned, there has been a decided change in speed and economy. Methods of observing and of computing have been standardized and this has greatly aided the work.

Since about 1904 all of the primary azimuths, in so far as was practicable, have been observed by the triangulation party during the progress of the work. It is believed that this plan gives the highest degree of accuracy, for the measurements are made under exactly the same conditions as the triangulation with which they are concerned, and the cost is very materially reduced.

TELEGRAPHIC LONGITUDES

The formation of the great telegraphic longitude net of the Coast and Geodetic Survey is a geodetic feat worthy of special note. No less than four transatlantic determinations have been made which serve to connect the longitudes of the United States with Greenwich and Paris, and more than 50 stations are included in the net which covers this country. Finally, through a transpacific determination made by the Survey, supplemented by a similar one

made by Canada, the last link in the telegraphic longitude circuit of the globe was completed, and thus nearly all of the longitude observations made in the world are united into one great single system, accurately correlated through this circuit.

THE TRANSIT MICROMETER

Among improvements made by the Survey to the instrumental equipment used in astronomic work only one will be mentioned. This is the transit micrometer used in the determination of time by stars at meridian passage. Although the transit micrometer had been in use at fixed observatories, it was not until the investigations made at the Coast and Geodetic Survey, in 1904, that its adaptability to portable transits was thoroughly proved. The many tests it has had in actual field work have shown for it many features of excellence. With its use, the relative personal equation between two observers is so small as to be masked by the accidental errors of observation and is certainly not more than one tenth as large as the average using the key. No interchange of observers is necessary, and the time of the determination of a difference of longitude is about one half the time taken by the older method.

THE FIGURE OF THE EARTH

The very important problem of determining the shape and size of the earth is probably the climax, from the scientific point of view, in the geodetic work of the Survey.

Reference has already been made to the use of the arcs of triangulation in determining the figure of the earth. When many arcs, both meridional and latitudinal, are all joined together on the same trigonometric and astronomic basis, the area method, developed in the Coast and Geodetic Survey since about 1901, is, without doubt, far superior to the arc method. In it are all of the features of the arc method, to which many important new features are added. Using the great system of triangulation in the United States to furnish the area factor and the many astronomical measures connected with the system to furnish the curvature factors, a value for the figure of the earth was derived which is of a very high degree of accuracy. The investigations and results obtained in this work are noteworthy contributions to geodesy. Some of the prominent features of this investigation are shown in the wide area treated, the large number of astronomic observations involved, and the unusual methods of computation used. Topographic irregularities within 4,000 kilometers of each astronomic station were considered, and account was taken of possible distribution of density beneath the surface of the earth. These features, together with the actual results obtained, make this a monumental work.

By a study of the station errors, or deflections in the verticals, which were developed when the astronomical and geodetic measures were compared, evidence was brought forth which established the fact that the condition of isostasy exists in the earth—a fact which is of interest and value to geodesy and geology.

These studies of the figure of the earth and isostasy have attracted the attention of the scientific world. Dr. Woodward, the distinguished geodesist, is authority for the statement that the work done by the Coast and Geodetic Survey on isostasy is the greatest contribution to geodesy since the time of Bessel and Gauss.

GRAVITY MEASURES

Another method of attacking this important problem of the earth's shape and size is by the use of the pendulum in the determination of gravity. The contribution of

the Coast and Geodetic Survey to this field of geodesy are given in the results of more than 30 foreign stations and of nearly 200 stations in the United States.

Happily the gravity conference held in 1882 endorsed the plan of using the invariable pendulum, and of employing the differential method of carrying on gravity work, and the Survey's present excellent equipment and methods are the direct results. In its present type of apparatus, known as the Mendenhall pendulums, the Survey has a form which for compactness, portability, precision and ease of operation ranks well among the highest in this field of endeavor.

Two features in recent gravity work are worthy of note. One is the application of the interferometer to the measurement of the flexure of the pendulum support, thus giving a direct measurement of this small quantity in terms of a wave-length of light. It is believed that the resulting corrections to the period of the pendulum are more accurate than those by the older static method where the corrections were derived under exaggerated conditions. The interferometer has been in use for about 8 years as a field instrument, and determinations of the flexure have been made at about 140 gravity stations, through a very wide range of conditions in piers and external vibrations.

The second feature worthy of note in recent gravity work is the deriving of the rate of the chronometers by Western Union time signals at noon—a distinct advantage over the older method. By it the local time observations are dispensed with, the time of occupation of a station is decreased and the labor of preparing the station greatly lessened, all of which contribute to a lowering of the cost per station occupied. In connection with this it is interesting to note that Assistant Schott in 1882 made the statement that

> Time furnished telegraphically by an observatory whose clock is protected from changes of temperature and pressure will be preferable to any local determination at a field station.

FIELD AND OFFICE FORCE

Little has been said of the men who have composed and do now compose the field and office force of the Coast and Geodetic Survey. What the Survey is and accomplishes is due to these men, and to the spirit which influences them. To them must be given the credit for much that the Survey has contributed to geodesy. It would be difficult to find a body of men of greater enthusiasm for, or a higher scientific attitude toward their work. They have a careful devotion, to duty and an interest in the success of the Survey and its work, a fact which has developed a corps of workers of unrivalled excellence.

They have ever been most alert to adapt new discoveries, made in the various fields of science, to the needs of the Survey, and to plan new and improved instruments; while to the theoretical work of geodesy they have added much by critical discussion and extensive study of results.

Workers must have tools, and this fine body of skilled observers would be seriously handicapped in their work if suitable equipment were not furnished them. The Survey is particularly fortunate in having a body of skilled artisans in the Instrument Division, under the supervision of a most highly efficient officer. In this division there have been designed or built nearly all of the instruments of precision which have helped so materially to place the Coast and Geodetic Survey in its present high position.

Of the relation of the geodetic work of the Survey to that of the world, as shown by its share in the operations of the International Geodetic Conference, only slight reference is here made, for this subject is dealt with in another address by the former

Superintendent Tittman who is much more capable of addressing you on this subject.

In the foregoing, the endeavor has been made to give some idea of the contributions which the Coast and Geodetic Survey has made to geodesy. Of necessity much has been omitted, but what has been given will bear witness that the world's geodesy has been greatly enriched by the work of the Survey.

A test of the greatness of the geodetic work of the Survey may be had in a review of the comments made by prominent men in other organizations and countries, by men who are well qualified to judge. They all accord to the geodetic work of the Survey a very high place in the geodesy of the world. One comment only will be here given as a fitting close to this brief review of the contributions made by the Coast and Geodetic Survey to geodesy.

Commandant Perrier, the French geodesist, in speaking of the work of the Survey, says:

> There is no example in the history of geodesy of a comparable collection of measurements, made with so much decision, such rapidity and such powerful means of action, and guided by such an exact comprehension of the end to be attained.

WILLIAM H. BURGER

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PITTSBURGH'S FIRST CHEMICAL SOCIETY[1]

IN *The Commonwealth*, a Pittsburgh weekly newspaper, of November 4, 1811, there was an advertisement to the effect that Dr. Aigster would deliver an introductory lecture on chemistry, Wednesday, November 6, at 3 P.M. in the grand jury room at the Court House. The advertisement concluded with this striking sentence:

> All friends of science will be gratuitously admitted.

The Pittsburgh Gazette, of December 20, 1811, carried the following advertisement:

> The subscribers to Dr. Aigster's Chemical Lectures are informed that the regular lectures will begin on Monday, the 16th of December, at the Laboratory, corner of Smithfield and Second Streets, at 3 o'clock P.M., to be continued from that time every Monday, Friday and Saturday at the same hour and at the same place. Further subscription will be received at the Laboratory.

That Dr. Aigster was not unlike many modern lecturers on scientific subjects is seen from an announcement in the *Gazette* of December 27, 1811, that Cramer, Spear and Eichbaum had just published a discourse, introductory to a course of lectures on chemistry, which included "a view of the subject and the utility of that science, delivered at Pittsburgh on the 6th of November by F. Aigster, M.D."

There is a copy of this discourse bound with Cramer's Pittsburgh Magazine Almanacks for 1816 and 1817 in the Carnegie Library of Pittsburgh. The lecture discusses in the words of Dr. Aigster, "the application of chemical knowledge in private and social life." It describes the applications of chemistry to agriculture, mining, cloth making, glass making, brewing, tanning, paper making and, last but not least, to cookery.

Some of Dr. Aigster's statements sound as if his lecture were delivered yesterday. Witness this:

> The time is come when America can shake off the yoke of foreign dependency for a number of the most necessary wants, whose first material, bountiful nature has scattered with lavish hands over this country.

And this:

> A laudable beginning has been made in the wool, flax and cotton manufactures. But it can never be expected that they will attain any high degree of improvement as long as the art of dyeing, which is altogether chemical, is not attended to.

[1] This paper was read before the Historical Society of Western Pennsylvania on January 25, 1916.

In a latter part of a lecture Dr. Aigster says that while the history of chemistry in America is short, it contains a few names which would do honor to the proudest nations of the ancient world. He mentions the names of Dr. Benjamin Rush, of Philadelphia, Dr. Samuel L. Mitchill, of New York, Dr. Woodhouse, of Philadelphia, Dr. M'Clean, of Princeton, Professor Silliman, of New Haven, Dr. I. Redman Coxe, of Philadelphia, Joseph Priestley, and Mr. Thomas Cooper, who he states was his successor as professor of chemistry at Dickinson College.

Following the discourse is a syllabus on chemistry which is divided into three sections:

1. General forces productive of chemical phenomena.
2. Of the general properties and relations of individual substances.
3. Chemical examinations of organized nature.

That Dr. Aigster was interested in the practicable application of some of his theories will be seen from the following note in the Pittsburgh Magazine Almanack for 1812:

> Proposals for the formation of a company for the purpose of establishing a combined manufactury of sulphurick acid (oil of vitriol), of nitrick acid (aqua fortis) and of allum have been lately issued by Dr. Aigster, formerly professor of chemistry in Dickinson College, Carlisle, now resident in Pittsburgh.

The note then goes on to outline the process and the prospects for success.

In the Directory of Pittsburgh for 1815, which was the first directory, Dr. Aigster's Christian name is given as Frederick, his residence "in the Diamond" and his profession as "physician and chymist."

Sarah Killikelly, in her history of Pittsburgh, says that perhaps out of the series of lectures by Dr. Aigster grew the Pittsburgh Chemical and Physiological Society.[1] This is no doubt true, as Dr. Aigster's name appears in the list of honorary members of the Columbian Chemical Society of Philadelphia, which was founded in 1811, and the Pittsburgh Society appears to have been modeled very closely after the Philadelphia Society.

At all events, a notice appeared in one of the weeklies requesting persons interested to "meet at A. M. Bolton's Academy Hall, Market Street, on Friday evening October twenty-ninth, 1813, at 6 o'clock, for the purpose of organizing the Institution and electing officers."

At the next meeting, on November 12, the following officers were elected:

President, Dr. B. Troost.
Secretary, J. B. Trevor.
Treasurer, S. Pettigrew.
Lecturer, Dr. E. Ramsey.
Librarian, A. M. Bolton.
Annual Orator, Rev. D. Graham.

At the time of the organization of this Chemical Society, the population of these United States was about 7,000,000 and of the borough of Pittsburgh about 7,000. Some of the advertisements which appeared in the papers at that time will give an idea as to why, with so small a population, there was a live interest in chemistry.

PAPER MAKERS WANTED

Two paper makers, one who is competent to superintend a paper mill and is well acquainted with the whole art and mystery of paper making, the other to work as a journeyman.

The highest price in cash will be given for a quantity of merchantable potash. Apply to Anthony Beelen.

GLASS BLOWING

Wanted, two or three sober lads, fourteen to sixteen years of age, as apprentices to above business.

[1] Killikelly, Sarah H., "History of Pittsburgh." B. C. and Gordon Montgomery Company, Pittsburgh, 1906.

Cash given for pot and pearl ash.

TREVOR AND ENCELL

DR. G. DAWSON

Family, patent and horse medicine, surgeon's instruments, paints of all kinds, spirits of turpentine, spices, perfumery, oils, varnish, etc.

ASHES

The subscriber will give 25 cents per bushel for any quantity of good oak and hickory ashes, delivered at his soap and candle manufactory, corner of Ferry and Third Streets.

NICHOLAS O'CALLAGHAN

NITRE

Warranted in its pure stage, refined by the subscriber and for sale at John McClean's commission warehouse. It may also be had particularly prepared for manufacturing gun powder, by CHARLES MUNNS, Gun Powder maker and Salt Petre refiner.

Well, to come back to the Chemical and Physiological Society. The advertisements in the papers after the initial meeting were very few. Newspapers were not so liberal with their space as now. A notice appeared in February, 1814, to the effect that there would be a lecture on "the singular properties and effects of nitrous oxide or, as it is sometimes called, the exhilarating gas, Friday evening, February 25, 1814."

On November 2, 1814, the *Mercury* carried the following advertisement:

A stated meeting of the Chemical and Physiological Society will be held at the usual place, on Thursday evening next, at 7 o'clock.

The punctual attendance of the members is particularly requested, in order to make the necessary arrangements for the delivery of the annual oration at the succeeding meeting.

The election of officers will be held on the 10th instant, agreeable to the constitution.

J. B. TREVOR, *Secretary*

There is no record as to what was the subject of the annual oration, but there is a record that at the meeting following the election Dr. Troost talked "on oxygen gas accompanied with several interesting experiments."

The Directory for 1815 tells something of the Society and gives a list of officers who were elected at the meeting on Thursday, November 10, 1814, in the following notice:

THE PITTSBURGH CHEMICAL AND PHYSIOLOGICAL SOCIETY

This society was formed in 1813, by a number of scientific gentlemen resident in Pittsburgh, and has since rapidly increased.

There are at present belonging to the society, a Library, Chemical and Philosophical apparatus, and a valuable cabinet of mineralogy.

Their meetings are held every two weeks, in a room appropriated for that purpose in the Court House.

President, Walter Forward.
Secretary, Harmar Denny.
Treasurer, Samuel Pettigrew.
Librarian, Lewis Peterson.
Lecturer on Chemistry, Dr. B. Troost.
Botany, M. M. Murray.
Anatomy, Dr. Joel Lewis.
Mineralogy, Dr. F. Aigster.
Astronomy and Natural Philosophy, Joseph Patterson.
Annalist, Aquila M. Bolton.
Annual Orator, J. B. Trevor.

Walter Forward, who is given as the President, was an attorney-at-law, who in 1819 became one of the twenty-six incorporators of the Western University of Pennsylvania, now the University of Pittsburgh. In 1841 he was appointed by President Harrison to be the controller of the United States and in that same year he was made Secretary of the Treasury of the United States by President Tyler.

Harmar Denny, who is given as the Secretary, was the son of Ebenezer Denny, who, in 1816, became the first Mayor of Pittsburgh. Harmar Denny, when he was elected Secretary, had just been graduated from Dickinson College where he had undoubtedly studied chemistry under Thomas Cooper who was professor of chemistry at Dickinson College from 1811 to 1814.

The election notice, signed by Harmar

Denny, appeared on November 15, 1814, and on December 14, 1814, the following notice appeared:

A special meeting will be held at the Society Hall next Thursday at half past six.

Harmar Denny, *Secretary*

Why a special meeting so soon after the election? Did Messrs. Troost and Trevor resent the fact that they were not reelected to their former positions, or had interest in things scientific declined in the borough? Perhaps it was the pressure of business, for less than a month after this notice the newly organized firm of Trevor, Pettigrew and Troost announced that the Western Eagle Lead Factory was in complete operation. The members of this firm later advertised that "they also manufacture, at their chemical laboratory, alcohol, ether, sweet spirits of nitre, aqua fortis, muriatic acid, red precipitate, calomel and chemical preparations generally."

At least one member of this firm, Dr. Troost, did not lose his interest in pure chemistry, for in 1827 he was elected lecturer in chemistry for the Pittsburgh Philosophical and Philological Society, of which Rev. Robert Bruce, the first chancellor of the University of Pittsburgh, was president.

But, to come back to the Chemical Society, it is almost certain that the Society was disbanded at the special meeting of December 14, 1814, for no other notices of meetings appeared in the newspapers.

It is interesting to know that the Pittsburgh Chemical Society was undoubtedly the third in the United States. It was preceded by two Philadelphia societies, the Chemical Society of Philadelphia, founded by James Woodhouse in 1792, and the Columbian Society of Philadelphia, founded in 1811.[2]

Pittsburghers have every reason to be proud of the fact that so early in the history of the city, which was then a frontier town, away on the other side of the mountains, there was a live interest in science, and, especially, in that branch of science which has contributed so much to the industrial progress of the city.

John O'Connor, Jr.
Mellon Institute,
University of Pittsburgh

[2] Smith, Edgar Fahs, "Chemistry in America," D. Appleton and Company, 1914.

THE SAN DIEGO MEETING OF THE PACIFIC DIVISION OF THE AMERICAN ASSOCIATION

ASTRONOMICAL SOCIETY OF THE PACIFIC

The Astronomical Society of the Pacific will hold sessions in San Diego on Thursday and Friday, August 10 and 11, at the time of the meeting of the Pacific Division of the American Association for the Advancement of Science. In these sessions the Astronomical Society of Pomona College will participate.

The opening paper of the program will be presented by Professor S. D. Townley, of Stanford University, president of the society. A number of other papers have been promised by astronomers of the Pacific Coast, and an interesting program is assured. A special feature of the program will be discussion of problems presented by the nebulæ. Attention is also called to the fact that the address on August 9 by the president of the Pacific Division A. A. A. S., Dr. W. W. Campbell, will be on the subject "What we know about Comets."

The titles of papers offered by members of the Society or of the Pacific Division for this meeting should be in the hands of the chairman of the program committee, R. G. Aitken, Mount Hamilton, California, before July 10, and abstracts should be submitted before July 29. It is especially requested that these abstracts be worded in popular language, as it is planned to print them in the daily press.

CORDILLERAN SECTION OF THE GEOLOGICAL SOCIETY OF AMERICA

A meeting of the Cordilleran Section of the Geological Society of America has been ap-

pointed in conjunction with the meeting of the Pacific Division of the American Association for the Advancement of Science, in San Diego, on the dates August 9, 10 and 11, 1916. Titles of papers from members of this society to be presented at this meeting should be sent to the secretary, J. A. Taff, 781 Flood Building, San Francisco, before July 20. An abstract of about 250 words should be submitted with each title. Papers will also be welcomed from members of the Pacific Coast Section of the Paleontological Society and from the Seismological Society of America who may attend this meeting, in case these societies do not also hold meetings.

Excursions in the vicinity of San Diego will be arranged for members of the Section who desire to see geologic features of this region which are of peculiar interest. Among these features may be mentioned the cliff section of Point Loma, the great Coronado sand-spit which has formed San Diego Bay, the marine terraces on San Clemente Island, and the pegmatite dikes near Pala and Mesa Grande in which valuable deposits of gem tourmaline, garnet and kunzite have been found. The high granite peneplain of the Perris Valley and the Salton Sink and irrigation projects of the Imperial Valley may also be reached by automobile from San Diego.

J. A. TAFF,
Secretary

PACIFIC SLOPE BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

THE first meeting of the Pacific Slope Branch of the American Association of Economic Entomologists will be held in conjunction with the meeting of the Pacific Division of the American Association for the Advancement of Science in San Diego, California, between the dates August 9 and 12, 1916. An important feature of this meeting will be the completion of the organization of the branch and the formulation of plans for future work.

Among the papers which have already been offered for the San Diego meeting are:

"Host Relations of Ecto-parasites," by Vernon L. Kellogg, Stanford University, California.

"Economic Syrphidæ in California," by W. M. Davidson, United States Bureau of Entomology, Walnut Creek, California.

"The Chrysanthemum Gall-fly," by E. O. Essig, University of California, Berkeley.

"Some Scale Insects of Oregon," by LeRoy Childs, Oregon Agricultural College, Hood River.

"The Fruit-tree Leaf Syneta, Spraying Data and Biological Notes," by George F. Mozenette, Oregon Agricultural College, Corvallis, Oregon.

Titles of other papers to be presented at this meeting, together with abstracts, should be submitted to the secretary before July 20.

E. O. ESSIG,
Secretary

UNIVERSITY OF CALIFORNIA

WESTERN SOCIETY OF NATURALISTS

THE first meeting of the Western Society of Naturalists will be held in San Diego on August 10 and 11, in conjunction with the meeting of the Pacific Division of the American Association for the Advancement of Science. The San Diego Natural History Society and the Pacific Coast Branch of the American Phytopathological Society will also participate in the meeting of the Western Society of Naturalists.

At these sessions a number of papers will be presented upon a wide range of topics of general biology which will be of interest to botanists and zoologists and also to the general public. Worthy papers upon more limited fields of zoology or botany will also be welcome. Titles of papers, together with brief abstracts, should be submitted to the secretary of the society, E. L. Michael, La Jolla, California, before July 20.

Among the papers already offered for this meeting are the following:

"Composition of the Rancho La Brea Fauna," by John C. Merriam, professor of paleontology and historical geology, University of California.

"Eugenics and War; and Isolation and Production of Germinate Species," by David Starr Jordan, chancellor, Stanford University.

"An Amateur Naturalist in Formosa," by Dr. Fred Baker, Point Loma.

"Biology's Contribution to a System of Morals Adequate for Modern Civilization," by W. E.

Ritter, scientific director, Scripps Institution for Biological Research, La Jolla.

"The Mutation Theory and the Species-concept," by R. R. Gates, acting associate professor of zoology, University of California.

Papers will also be presented by Professor H. M. Hall, Dr. Joseph Grinnell and Mr. Tracy I. Storer, of the University of California; by Dr. D. T. MacDougal, Desert Botanical Laboratory, Tucson; Professor Harry Beal Torrey, Reed College, Portland, and others.

On Thursday afternoon, August 10, the session will take the form of a conference upon the tuna fisheries of southern California. A consideration of the tuna fisheries is especially appropriate at this time in view of the recent development of this industry, the establishment of tuna canneries at San Diego and other ports of southern California, and the work of the *Albatross* of the United States Bureau of Fisheries in tuna investigations in southern California waters this summer.

BARTON W. EVERMANN,
President

SCIENTIFIC NOTES AND NEWS

DR. HENRY M. HOWE, emeritus professor of metallurgy in Columbia University, has been appointed honorary vice-president of the Iron and Steel Institute of Great Britain.

THE Paris Academy of Sciences has elected as correspondent in the section of medicine and surgery in succession to the late Professor Mosso, of Turin, Dr. Bergonié, professor of biological physics and medical electricity at Bordeaux.

AN honorary degree was conferred by the University of California at its fifty-third commencement exercises on John Stillman, professor of chemistry in and vice-president of Stanford University.

SAMUEL GIBSON DIXON, Pennsylvania state health commissioner and president of the Philadelphia Academy of Natural Sciences, received the degree of Sc.D. from Lafayette College at the annual commencement on June 14.

AT the annual commencement of the University of Cincinnati, on June 10, the honorary degree of doctor of science was conferred on Professor John Uri Lloyd, Cincinnati, known for his contributions to chemistry and pharmacy.

GEORGE FREEMAN PARMENTER, Merrill professor of chemistry in Colby College, has been given the degree of doctor of science by the college.

AT its recent commencement the University of Pennsylvania conferred on Daniel Lincoln Wallace, the degree of doctor in chemistry.

DR. CHARLES WILLEMS, surgeon of Ghent, has been elected a foreign correspondent of the Paris Academy of Medicine.

AT the annual meeting of the American Academy of Medicine, held in Detroit, on June 12, the following officers were elected: president, Dr. Jacob E. Tuckerman, Cleveland; vice-presidents, Dr. Frederick L. Van Sickle, Olyphant, Pa., and Dr. Ray Connor, Detroit, and secretary, Dr. Thomas W. Grayson, Pittsburgh.

DR. ALLEN K. KRAUSE, of the Saranac Lake (N. Y.) laboratories, will take charge of the work on tuberculosis in the Phipps laboratories of the Johns Hopkins University, made possible by the recent gift of Mr. Kenneth Dows.

DR. H. R. WAHL, associate in pathology, Western Reserve Medical School, has been elected director of laboratories in the new Mount Sinai Hospital.

PROFESSOR SELSKAR M. GUNN, director of the division of hygiene of the Massachusetts State Department of Health, has resigned.

WILLARD J. FISHER, head of the department of physics at the New Hampshire College, has retired to devote himself to research work.

FREDERIC A. HARVEY, Ph.D., has resigned from the faculty of Syracuse University to accept a position as technical physicist with the Solvay Process Co., at Syracuse, N. Y.

PROFESSORS W. B. CANNON, of Harvard University, Frederic S. Lee, of Columbia University, and William H. Park, of New York University, and Drs. McCoy and Eichorn, of

Washington, on June 19, spoke in Washington before the senate committee on agriculture and forestry in opposition to the bill now before congress, which provides for an investigation of animal experimentation throughout the country. A considerable delegation of antivivisectionists urged the passage of the bill.

A COMMISSION constituted by the International Health Board of the Rockefeller Foundation sailed on the *Almirante* on June 14, on a trip to various points of South America where yellow fever is still reported to exist. The commission is headed by Major General William C. Gorgas, U. S. Army, who has obtained four months' leave of absence for this purpose. The other members are Assistant Surgeon General Henry R. Carter, U. S. P. H. S., clinician; Dr. Juan Guiteras, head of the Public Health Service of Cuba, clinician and general adviser; Major Theodore C. Lyster, M. C., U. S. Army, clinician; Major Eugene R. Whitmore, M. C., U. S. Army, pathologist; Sanitary Engineer William D. Wrightson, U. S. P. H. S., sanitary engineer, and Harry H. Wakefield, secretary.

DR. ALLERTON S. CUSHMAN, of the Institute of Industrial Research, Washington, D. C., gave an address before Sigma Xi at the Worcester Polytechnic Institute on June 5, 1916, on "Science and Civilization."

WE learn from the *Journal* of the American Medical Association that a memorial service to the late Dr. Frank W. Reilly, for many years assistant commissioner of health of Chicago, and at one time secretary of the Illinois State Board of Health, was held on June 21, when the Frank W. Reilly Public School at School Street and Lawndale Avenue was dedicated. The principal addresses were delivered by Superintendent of Schools John D. Shoop; President Jacob M. Loeb, of the Board of Education; Dr. Arthur R. Reynolds, former health commissioner, and Dr. Alfred C. Cotton.

ON the occasion of the meeting of the Western Reserve University Medical Alumni Association, June 8, 9 and 10, President Charles F. Thwing formally accepted on behalf of the university, its trustees, etc., portraits of two former professors in the medical school, namely, Dr. Gustav C. E. Weber, formerly professor of surgery, and Dr. Hunter H. Powell, formerly professor of obstetrics and diseases of children. Presentations on behalf of the Alumni Association were made by Drs. W. T. Corlett and A. H. Bill, respectively.

DR. SAMUEL G. DIXON, president of the Academy of Natural Sciences, has proposed to the mayor of Philadelphia that the statue of Joseph Leidy, now badly placed on City Hall Square, should be erected, at least temporarily, near the academy in the greenery of Logan Square.

AMONG those killed in the naval action in the North Sea on May 31 was Commander H. L. L. Pennell, one of officers of the *Terra Nova* in the British Antarctic Expedition of 1910.

THE meeting of Scandinavian naturalists will be held in Christiania on July 10 to 14.

THE Yorkshire Agricultural Union has decided to open a national fund for the representation of agriculture in the British parliament by practical agriculturists.

THE Graduate School of the University of Illinois has recently made an appropriation for a geological expedition to Hudson Bay during the summer of 1916. The work will be in charge of Professor T. E. Savage and Dr. F. M. Van Tuyl, of the department of geology, who will be in that region from the latter part of June to the middle of September. It is planned to examine the outcrops and make detailed collections of fossils along most of the larger rivers south of the Churchill on the west side of the bay, in an effort to obtain more definite information concerning the Paleozoic succession and the ancient sea connections in that part of the continent. Evidences of recent elevation of the shore line, and other features will also be studied.

THE publication of agricultural bulletins for the benefit of the farmers of New York state will be discontinued for some time because the governor vetoed the legislative printing appropriation. He vetoed it because, despite

his warning to the legislature, the bill proposed to appropriate the money, about $200,000, in a lump sum instead of by items. His veto cuts off all provision for the expense of legislative printing this year. The Geneva and Cornell experiment stations have had about $60,000 apiece yearly for the printing of reports and bulletins, and this money has been appropriated under the head of legislative printing. Reports of all state institutions have been covered under that head. Bulletins such as the agricultural experiment stations have issued throughout the year for the information of farmers have been officially regarded as anticipating parts of the annual reports of the stations. Part I. of the annual report of the college has comprised the report itself and technical bulletins; Part II. has been made up of the matter intended for popular use, such as bulletins of general value and the reading course lessons of the year.

UNIVERSITY AND EDUCATIONAL NEWS

Mrs. Russell Sage has given $75,000 to Knox College of Galesburg, Ill., to make possible the securing of the amount to complete its half-million-dollar endowment fund.

The alumni of the University of California Medical School have offered to give $400 a year for five years to maintain the William Watt Kerr scholarship in medicine in honor of Dr. Kerr, clinical professor of medicine in the University of California.

Miss Charlotte Emily Beckwith has bequeathed one half of the residue of her estate, which amounts to about £8,000, to the Victoria University of Manchester in aid of the "John Henry Beckwith Scholarship" founded by her mother.

A large company of representatives of the scientific and technical press were received at the Imperial College of Science, South Kensington, on May 31 by the Right Hon. Arthur Dyke Acland, chairman of the executive committee of the governing body, and, with the professors and other members of the staff, took them round the institution. Mr. Acland referred to the memorial which has just been presented to Lord Crewe by the professors of the college, urging the importance of securing that a larger proportion of young men in this country should be trained in scientific methods with a view to industrial research. The suggestion is that a grant of a quarter or half a million pounds, in addition to the quarter of a million (as against Germany's million and a half) which the state annually grants to the universities might profitably be used to provide an adequate number of bursaries for secondary-school boys of 16 to 18 years of age, to be followed by the offer of government scholarships tenable at a university.

Professor Mary Whiton Calkins, of Wellesley College, has been appointed lecturer on the Mills Foundation in the department of philosophy of the University of California for the half year ending December 31, 1916—the lectureship held for the past year by Professor George H. Palmer, of Harvard University.

The vacancy in geology in the University of Kansas, caused by the resignation of Professor W. H. Twenhofel, has been filled by the election of Dr. Raymond C. Moore, of the University of Chicago.

At the June meeting of the board of regents of the University of Nebraska Dr. Raymond J. Pool was elected permanent head of the department of botany. Professor Pool had been acting head of the department since the death of Professor Bessey in February, 1915.

Dr. Charles C. Adams has been promoted to the professorship of forest zoology in the newly formed department of forest zoology in the New York State College of Forestry at Syracuse University.

As assistant professor of industrial hygiene of the medical college of the Ohio State University, Dr. Emery R. Hayhurst, an authority on the subject of occupational diseases and the relation of industrial problems to the preventable diseases caused by workshop conditions, has resigned as chief of the division of occupational diseases of the state department of health and will devote his entire time to the Ohio State Medical College.

At the last meeting of the corporation of the Massachusettts Institute of Technology promotions and appointments were made to the instructing staff as follows: From assistant to associate professor Daniel F. Comstock (theoretical physics), George L. Homer (topographical surveying), C. L. E. Moore (mathematics), Ellwood B. Spear (inorganic chemistry), William E. Wickenden (electrical engineering). Instructors were promoted to assistant professorships as follows: James M. Barker (structural engineering), Ralph G. Hudson and Waldo V. Lyon (electrical engineering), Earl B. Millard (theoretical chemistry). Dr. Frederick G. Keyes was appointed associate professor of physico-chemical research.

DISCUSSION AND CORRESPONDENCE

SOME FUNDAMENTAL DIFFICULTIES OF MECHANICS

A long and interesting exchange of views on the fundamental equation of mechanics, which has taken place in the columns of Science, has led me to review some old notes in that connection. It has seemed to me that the question may be viewed from two different points, that of the systematizer and that of the teacher. The former desires an equation, fundamental in that from it he can develop the science most easily. The latter must consider as the fundamental principles those which appeal most directly and forcibly to the student, which enable the student to progress most easily, with rapidity and security. By *the student* I mean the average student, who has much experience of a mechanical nature, but is unaccustomed to logic and cares little about unity.

To the teacher of mechanics students in masses, that is, to nearly every mechanics or physics teacher, even in college and technical school, the first-named viewpoint is unimportant as compared with the second. His business is to diagnose the student's difficulties, and then to obviate or remove them. Some of these difficulties are inherent in the laws of mind and matter.

Any teacher will admit that to the average student the descriptive, phenomenological, attitude toward mechanics is quite too rarefied, too impersonal. Professor C. R. Mann has well said:

> To a beginner pushes and pulls are the real forces.

The beginner can imagine himself pushing or pulling, exerting an effort and taking an interest. Descriptively, it has been questioned whether the concept of force is of much value in mechanics; but the sense and memory of effort give the student his starting point, and the teacher must begin kinetics with force as well as with acceleration and mass.

When we exert effort we observe we either change the motion of bodies, or change the relative positions of bodies or of their parts, hence the forms of bodies. During such changes of position or form, more or less temporary changes of motion occur.

Hence we all quite unnecessarily infer that when the motions of bodies are changed, or their relative positions, or their forms, there must be something going on analogous to an effort; this we call force, and we say that the above effects of effort are the effects of force.

Moreover, we observe that while the changes of relative position or form of bodies due to our effort may persist after we have ceased to exert effort, on the contrary the motion which has been produced by an effort does not continue, it always diminishes and finally ceases. We note that the effort needed for the production or increase of motion depends on the contact of the body acted on with other things, as soil, pavement, ice; water, if floating; oil, if lubricated; air, if swinging suspended; and also on the form of the body, flat or jagged or round. In some cases the production of motion is harder, in others easier, the duration of the motions is shorter or longer, but sooner or later the motions end in rest. If we want a thing to keep going we have to keep pushing or pulling; and this without exception in all our bodily experience.

Hence we hastily but naturally conclude that rest is the natural state of all bodies, and that for the maintenance of even constant motion continuous effort, or force, is necessary.

It has been pointed out that the scholastic

dictum about the necessity of force for the maintenance of motion is thus a consequence of common experience, a deduction of "common sense," which is the result of common experience. And while the common experience of boys and young men is changeable from age to age and different from one culture level to another, while men in the age of stone clubs or in the days of the stage coach had a range of common experience vastly different from what they have in an era of electricity and gasolene, nevertheless this element of terrestrial experience persists in them all—to maintain motion force must be continuously exerted; force lacking, rest supervenes.

Galileo's principle of inertia, then, Newton's first law of motion, is not a deduction of common sense, because it contradicts common experience. Only uncommon experience, interpreted by an uncommon mind, could arrive at it; and it is a fact that the world waited many ages for a genius to arise, fly in the face of common terrestrial experience, announce that the immediate consequence of force is acceleration, and interpret the inevitable extinction of unsupported terrestrial motions by the hypothesis of a force of friction, always opposing the existing motion and producing a negative acceleration. And the clear grasp of the inertia principle could only follow the study of a frictionless system.

Here we have the first difficulty of kinetics; its first law contradicts the student's common sense and all his ingrained mechanical experience. I doubt that many students, seeing the experiment for coefficient of friction, with horizontal slab, pulley and cord, actually interpret the slow uniform motion of the block in terms of two equal and opposed horizontal forces, producing each its own acceleration. It seems too far fetched; rather say, if you stop pulling the slab stops—and have done with it. And so with all the movements of wind and water; they go on because somehow they are driven. And so also Kepler interpreted the motion of the planet Mars in its orbit as due to a forward tangential force arising no doubt in the sun; and the schoolmen said that bodies fall with speeds proportional to their weights —which is roughly true for snowflakes and raindrops.

Change of motion, quantitatively called acceleration, is an idea rather remote from common experience. Every player of games is familiar with it in a crude way, but that it is a measurable quantity, or worth measuring, never entered any head before Galileo's. This is not at all remarkable, when we consider that speed is not given us by direct measurement, but only by simultaneous direct measurements of distance and time; much less are we given the rate of change of speed. The beginner has no real experience with acceleration as a measurable quantity; it is the rate of change of a rate of change, and too abstract for most people. It does have a connection with effort; to throw a ball fast is harder than to throw it slow; but I doubt if the average beginner ever has gone beyond that—and certainly many a student of calculus never connects this rough experience with d^2x/dt^2. In fact, we can not get differential expressions by measurement; Kepler's planetary laws and Galileo's laws of falling bodies are either integral expressions representing their tables of length[1] and time measurements, or are deduced from these integral expressions. Beginners do not of their own accord take the trouble to construct such tabulations or to differentiate twice the resulting integral expressions; in fact, few can do this, or at first realize what it all means when they are made to do it.

Our most continuous effort is to keep ourselves or other objects off the ground; the next most familiar, to set objects in motion upward, a motion which, unless some obstacle prevents, is sooner or later reversed into a motion downward. We say, as if an antagonistic effort were opposing ours, that the earth exerts a downward force upon us and all things near it; it is able to change their forms or to set them in motion downward.

While our sensations of effort are only qualitative, telling us of more and less, but not of how much, we assign measure to this earth effort, or force, or weight, by saying that its

[1] Angles are measured by arcs of graduated circles.

size is twice as great when it pulls on two exactly like objects together as it is when it pulls on only one of them; and conversely we use this pull to measure the elastic force of a spring, the relative magnitudes of different bodies, etc. This notion, that the magnitude of earth pull is proportional to the number of otherwise equal things on which it acts, is fundamental, and so familiar as to seem axiomatic; it is instinctive, as E. Mach would say.

The study of the downward motion of bodies affected by their own weight and only slightly by friction was a lifelong interest of Galileo. Directly or indirectly he showed two things; that they fall equal distances in equal times, and that unequal distances of fall are proportional to the squares of the times of fall. Differentiation of the latter showed that the gravitational acceleration is constant during the time of fall; the former showed it to be the same for all things, independently of their weight or material.

The last conclusion leads to an appreciation of another difficulty in the study of mechanics, if we take into account a law of psychology, well stated in the following quotation from William James:

> . . . any number of impressions, from any number of sensory sources, falling simultaneously on a mind which has not yet experienced them separately, will yield a single undivided object to that mind. The law is that all things fuse that can fuse, and that nothing separates except what must.
>
> The singling out of elements in a compound. It is safe to lay down as a fundamental principle that any total impression made on the mind must be unanalyzable so long as its elements have never been experienced apart or in other combinations elsewhere. The components of an absolutely changeless group of not-elsewhere-occurring attributes could never be discriminated. If all cold things were wet, and all wet things cold, if all hard things pricked our skin, and no other things did so: is it likely that we should discriminate between coldness and wetness, and hardness and pungency, respectively? If all liquids were transparent and no non-liquid were transparent, it would be long before we had separate names for liquidity and transparency. If heat were a function of position above the earth's surface, so that the higher a thing was the hotter it became, one word would serve for hot and high. We have, in fact, a number of sensations whose concomitants are invariably the same, and we find it accordingly impossible to analyze them out of the totals in which they are found.

Now to lift a stone vertically we have to exert an effort, neutralizing the earth's pull upon it, its weight. To throw the same stone horizontally, to accelerate it, we have also to exert effort; and the harder the stone is to lift, the harder it is to throw. (If we refine this crude observation by experiment, we find an exact proportionality between the weights of objects and the efforts or forces required to accelerate them equally.) Hastily generalizing, but most naturally, we say that stones are hard to throw, gates hard to swing, not in proportion as, but *because* they are heavy. To ordinary observation the accelerating and the gravitational efforts always increase and decrease exactly together; they do not tend to become discriminated, we do not abstract them separately.

To exact observation, however, a difference does show itself. The same stone weighed in a spring balance would elongate the spring less in low latitudes than in high (we tell our classes this; did any one ever try it?). The same pendulum vibrates more slowly in low latitudes than in high, as Richer found in 1672–3. We can imagine a man lifting and throwing a ball at the bottom and again at the top of a tower four thousand miles high, observing a notable change in the weight of the ball and yet none at all in the difficulty of throwing it. But such observations under terrestrial conditions have to be accurate to less than ½ per cent., far more accurate than the unaided sense memory can be. To the average man a heavy thing is also hard to throw, because it is heavy; a fact which stands as a formidable obstacle to a clear grasp on the idea of mass; to most students mass and weight are forever identical, except that the book says to divide weight by g to get mass.

In an old copy of Wells' "Natural Philosophy" I find the following problem and answer, which may serve as an illustration:

Why will a large ship, moving toward a wharf with a motion hardly perceptible, crush with great force a boat intervening?

Because the great mass and weight of the vessel compensates for its want of velocity.

Which shows that the author of this famous book did not discriminate between mass and weight in a case where weight as force does not enter.

This confusion of mass and weight can not be helped by pseudo-definitions which attempt to evade the essentially kinetic nature of the mass concept. As is well known, Newton, in the "Principia," defined mass as the product of density and volume, and equivalent to quantity of matter. Neither of these statements has any value, as neither brings out the essential fact that a body subject to acceleration displays a constant characteristic property, which is the core of Newton's own treatment of the problem of accelerated motion. Another more recent definition states that mass is the result obtained by weighing with a balance scale. This can not help a student very much. The balance scale was known for centuries before Newton, and had mass been so easily defined it would hardly have been left for him to discover the fact of its existence and importance. The fact is, that mass is a concept of kinetics, not to be reached at all by static experiments, and not to be clearly discovered by kinetic experiments affected by friction. It came into science by way of Mars and the moon, and was then read into terrestrial experience. The "balance scale" gives us mass not directly, but by interpretation, even as does the Jolly balance. It is not always true that "in physics sensible people define things the way they do them."

Students in general seem to have no serious difficulty with the equality of push and counter-push, of friction and counter-friction, of action and reaction. Trouble does come up in the identification of actions and reactions, and in the realization that these always act upon different things, in opposite directions in the same straight line.

As illustrations, take two quotations, the first from Wells's "Natural Philosophy," of the sixties, the other from a recent book:

The centrifugal force is that force which impels a body moving in a curve to move outward or fly off from a center. The centripetal force is that force which draws a body moving in a curve toward the center, and compels it to move in a bent, or curvilinear course. In circular motion the centrifugal and centripetal forces are equal, and constantly balance each other. If the centrifugal force of a body revolving in a circular path be destroyed, the body will immediately approach the center; but if the centripetal force be destroyed, the body will fly off in a straight line, called a tangent.

Suppose the horse drawing a sled increases his speed. Two reactions now oppose the pull applied to the sled. One, friction, opposes the slipping of the sled over the ground; the other, due to inertia, opposes increase of speed. These two together are equal and opposite to the pull exerted on the sled.

These are only cases of confusion such as come up in every physics or mechanics classroom; centrifugal and centripetal forces balancing each other in circular motion, both acting on the same thing; friction and the "vis inertiæ" are the reactions to the pull exerted by a horse.

When one has endeavored to point out the nature of a difficulty, it is natural to ask him for the remedy. I am not pretending that I have found remedies for the difficulties mentioned above, some of which seem to be imposed upon us by the constitution of our minds and the environment in which the race has grown up. The only thing to do is to make every endeavor to break up the satisfaction of the student with the concepts which he has unconsciously formed, to try to contrive striking experiments which shall, for example, make plain that something more than the notion of weight is needed for their explanation, and, especially, to familiarize him with the concept acceleration and the various ways of arriving at its value, theoretically and practically. The teacher has almost to strive against instinct in the treatment of the laws of motion, and some people can never be expected to grasp them.

Willard J. Fisher

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THE TEACHING OF ELEMENTARY DYNAMICS

TO THE EDITOR OF SCIENCE: The communication of Professor Wm. Kent in SCIENCE of December 24, 1915, on the subject heading is particularly interesting as a critical analysis, but the writer does not think Professor Kent's proposed method of teaching the subject is the best way.

As further discussion is invited, a method will now be given, very briefly, that is clear and brief and that beginners readily comprehend.

1. Let a *spring-balance* be graduated with a set of standard pound weights (metal pieces) at sea level, say at latitude 45°, where $g = 32.174$ ft. per sec. per sec. is the acceleration due to gravity. Now suppose a certain body there, when hung from the spring-balance, to depress the pointer until it reads W pounds; then the pull of the earth at this point on the body is exactly W pounds force.

2. Let the same body be hung from this same spring-balance *at any other point* where the acceleration of gravity is g_1 and suppose the pointer reads W_1 pounds; then the pull of the earth on the body at the second place, is W_1 pounds force.

3. State as an experimental fact that

$$W_1/g_1 = W/g. \tag{1}$$

This simple equation gives the solution to a number of problems involving weights as measured on the standard spring-balance at different latitudes and altitudes. Give several of these problems.

4. *Mass.*—Mass of a body means the quantity of matter in the body. It is not supposed to alter in amount by changing the position of the body relative to the earth or to be affected by chemical changes, the expansion or contraction of the body or by any change of the body from a solid to a liquid or gaseous state or a reverse change.

If the body weighs W pounds on the standard spring-balance at the place where the acceleration of gravity is g ft. per sec. per sec., the mass of the body will be assumed to vary with W/g, which is likewise unaltered, by eq. (1), by any change of place, volume or condition. If M denote the numerical measure of the mass of the body in question, we can write,

$$M = k\,W/g,$$

where k is a constant for any chosen set of units. For the engineer's system, $k = 1$ and,

$$M = W/g. \tag{2}$$

We have now a precise numerical measure of the mass of a body and observe that, at the same place, the mass of a body is directly proportional to its weight. It is not affected by a change of place, by any chemical changes within the body or by any alteration in volume. The student has now a clear-cut, definite idea of the mass of a body and of its measure in the engineer's system. When $W = g$, $M = 1$; hence the unit of mass is the quantity of matter that weighs g lbs. on the spring balance at the place where the acceleration is g.

If W is the spring-balance weight at sea level, 45° latitude, where $g = 32.174$, then $M = W/32.174$ and the unit of mass is the quantity of matter in a body weighing 32.174 lbs. on a spring-balance at sea level, 45° latitude or 32.174 lbs. on a lever balance anywhere.

5. Mass is a fundamental concept and being clearly understood, "*density*" can be defined, for a homogeneous body, as the ratio M/V, where V is the volume of the body of M units of mass.

6. From eq. (2), we have,

$$W = Mg. \tag{3}$$

Now if an unbalanced force of F lbs., acting on a body of M units of mass, produces in it an acceleration of a ft. per sec. per sec., the formula giving the relation between F, M and a must reduce to (3) when $F = W$, $a = g$.

Such a formula is

$$F = Ma. \tag{4}$$

This is one of the fundamental formulas of mechanics and the arguments in favor of it should be given as fully as possible, somewhat as in Routh's "Dynamics of a Particle," pp. 18–23 and in connection with Newton's "Three Laws of Motion." The formula is equivalent to the second law, of which the first is a corollary. The formula is readily verified by use of Atwood's machine when $a < g$.

7. From (4), other well-known formulas, $Ft = Mv$, $Fs = \frac{1}{2}Mv^2$, etc., can at once be de-

rived; also by aid of (4) and Newton's third law, that "action and reaction are always equal and contrary" the problem of impact of two particles can be solved.

8. By pursuing the course outlined above, the student has to learn and thoroughly understand, only two simple formulas, $M = W/g$, $F = Ma$.

Wm. Cain

Chapel Hill, N. C.

GRAVITATION AND ELECTRICAL ACTION

In a paper to be published by the Academy of Science of St. Louis, evidence will be presented which appears to show conclusively, that gravitational attraction is diminished by electrical charges on the acting masses. The suspended masses of the Cavendish experiment are wholly enclosed in a shield of sheet metal. The small observation window is covered with wire gauze. When a knob terminal connected with the influence machine is moved towards or away from a knob terminal connected with the large attracting masses, the suspended masses slowly move to and fro around the vertical line of suspension. No disruptive discharges occur. It is found that gravitational attraction is decreased by either positive or negative electrification. By the to-and-fro movement of the knob terminal, the amplitude of vibration can be gradually increased from 2.5 minutes of arc to 50 minutes. It has been established by experimental methods that these results are not due to heat effects.

Francis E. Nipher

THE PRODUCTION OF RADIUM

To the Editor of Science: On page 799 of the June 2, 1916, issue of Science a statement is made in regard to the production of radium by the Standard Chemical Co. in the year 1915, which is not in accord with facts, and I wish to make this correction. The actual amount of radium produced by the Standard Chemical Co. during 1915 was slightly more than 3 grams of radium element and of this the larger proportion was produced in the first three months of the year from radium which was in process of treatment during the latter part of 1914.

In this same article the production of radium at a cost of $37,599 per gram by the National Radium Institute Inc. working in cooperation and under the supervision of the Bureau of Mines, is compared with the market price of radium of $120,000 a gram. The radium produced by the National Radium Institute was obtained from high-grade carnotite ore treated without concentration, and the cost of production under these conditions is not properly comparable to the cost of production or the selling price of radium from lower grade ore or concentrates.

Applying the Bureau of Mines process to unconcentrated ore containing about 1.5 per cent. of uranium oxide (which is higher than the average carnotite ore) makes the cost of production nearer $70,000 than $40,000 per gram. Since this is practically the condition under which commercial producers of radium must operate, it would be ıairer to compare cost of production by the Bureau of Mines process on this basis, rather than on the basis of the uncommercial and somewhat artificial conditions, connected with the treatment of the 1,000 tons of high-grade ore. Concentration of the low-grade ore, if practised, naturally reduces the efficiency of extraction, and in this way would raise the cost of production.

While it is true that the war cut off practically the entire European market to radium producers, it must be added that the growing American market for radium has been very adversely influenced by the widespread publishing of statements, from the United States Bureau of Mines, similar to the statement in Science which we are criticizing. The general effect of these statements has been to lead prospective purchasers of radium to believe that radium would soon be available at enormously reduced prices. Emphasis being laid by the Bureau of Mines on the exceptionally low cost of production, and in general no mention being made of the fact that this low cost of production was in a large measure due to the abnormal and uncommercial conditions under which the Bureau operated.

As regards ore concentration it is also interesting to note that the method used by the Bureau of Mines is one which has been used

by the Standard Chemical Company for the past four and a half years, and on the basis of figures published by Dr. Charles L. Parsons in the May number of the *Journal of Industrial and Engineering Chemistry*, it is not evident that the method is satisfactorily efficient, when applied to the treatment of low-grade carnotite ore.

CHARLES H. VIOL

PITTSBURGH, PA.,
June 3, 1916

SCIENTIFIC BOOKS

RECENT BOOKS IN MATHEMATICS

Algebraic Invariants. By LEONARD EUGENE DICKSON, Professor of Mathematics, University of Chicago. New York, John Wiley and Sons, 1914. Pp. 100. $1.25.

A Treatise on the Theory of Invariants. By OLIVER E. GLENN, Ph.D., Professor of Mathematics in the University of Pennsylvania. Boston, Ginn and Company, 1915. Pp. 245.

Contributions to the Founding of the Theory of Transfinite Numbers. By GEORG CANTOR. Translated and Provided with an Introduction and Notes by PHILIP E. B. JOURDAIN. Chicago and London, The Open Court Publishing Company, 1915. Pp. 211. $1.25.

Problems in the Calculus. With Formulas and Suggestions. By DAVID D. LEIB, Ph.D., Instructor in Mathematics in the Sheffield Scientific School of Yale University. Boston and New York, Ginn and Company, 1915. Pp. 224.

Diophantine Analysis. By ROBERT D. CARMICHAEL, Assistant Professor of Mathematics in the University of Illinois. New York, John Wiley and Sons, 1915. Pp. 118.

Historical Introduction to Mathematical Literature. By G. A. MILLER, Professor of Mathematics in the University of Illinois. New York, The Macmillan Company, 1916. Pp. 295.

An invariant is any thing—a property or a relation or an expression or a configuration—that remains unaltered when other things connected with it suffer change. In this very comprehensive but essential meaning of the term, the notion is probably as ancient as the human intellect. Certainly in historic time the appeal of the idea has been universal. It has been said that science may be defined as the quest of invariance. Doubtless that quest is an essential mark of science but it is not peculiar to science. For the problem of invariance, the problem of finding permanence in the midst of change, arises out of the flux of things to confront man in all departments of life. And so it is that the search for what abides is not confined to science but is and always has been the chief enterprise of philosophy and theology and art and jurisprudence. It is, however, in mathematics that the notion of invariance has come to the clearest recognition of its character and significance. In this respect the notion in question has had a history like that of all other great ideas that have slowly and at length become available for the processes of logic.

The oldest and now most elaborate portion of the mathematical doctrine of invariance is about as old as American independence. Though now an imposing theory, its beginning was like a mustard seed. It began, not in ratiocination, but in an observation—mathematics indeed depends even more upon observation than upon formal reasoning. It began in what was in itself a very small observation, an observation (1773) by Lagrange that the discriminant of the quadratic form $ax^2 + 2bxy + cy^2$ remains unaltered on replacing x by $x + \lambda y$. The next important step was taken by Gauss in 1801 and the next by Boole in 1841. Incited by Boole's beautiful results, the English mathematicians, Cayley and Sylvester, entered the field, the former producing in rapid succession his great memoirs on Quantics and the latter his brilliant investigations in what he conceived more poetically as the Theory of Forms. The interest so aroused quickly passed to the continent engaging the great abilities of such mathematicians as Aronhold, Hermite, Clebsch, Gordan and others. The result is the colossal doctrine variously styled the algebra of quantics, the theory of algebraic invariants and covariants, and the theory of forms.

It is to this doctrine that Professor Dick-

son's book gives the beginner an admirable introduction. It is, I say, for beginners, for it presupposes only a fair knowledge of analytical geometry and the differential calculus. The book is much larger than it appears to be, being very compactly written, the author having the art of getting a maximum of results with a minimum of talk. Yet the exposition is remarkably clear, uniting the two stylistic virtues of precision and conciseness. The work is composed of three parts. The symbolic notation is reserved for part III. Geometric interpretation is emphasized. In part I. linear transformation is alternately interpreted non-projectively and projectively; that is, on the one hand as working a change of reference configuration, and on the other as merely effecting a lawful transfer of attention from old loci (or envelopes) to new ones referred to the old configuration. Part II., which is mainly concerned with the properties of binary forms, deals with such matters as homogeneity, weight, transformation products, annihilators, linear independence, Hermite's reciprocity law, etc. The canonical form of the quartic is found and the equation is solved. Part III., which occupies 38 of the book's 100 pages, is devoted to a presentation and use of the symbolic method of Aronhold and Clebsch. In passing the author notes that this method is equivalent to the previously invented but relatively cumbrous hyperdeterminant method of Cayley. This part and indeed the book may be said to culminate in Hilbert's theorem regarding the expressibility of the forms of a system in terms of a finite number of them and the use of the theorem in proving the finiteness of a fundamental system of covariants of a set of binary forms.

It seems unfortunate that Professor Dickson did not deem it wise or find it practicable to set forth the matter of this volume in its natural relation to the theory of groups. Perhaps some one will some time write for beginners a book on transformations, groups and invariants with applications.

Professor Glenn's treatise is somewhat more extensive than Professor Dickson's. It, too, is introductory, beginning with a variety of simple considerations. Both the symbolic and the non-symbolic methods are explained and employed. Geometric interpretations are given and some connection with the group concept is made. The book comprises the following nine chapters: the principles of invariant theory (32 pages); properties of invariants (7 pages); the processes of invariant theory (40 pages), dealing with operators, the Aronhold symbolism, reducibility, concomitants in terms of roots, and geometric interpretations; reduction (46 pages), concerned with Gordan's series, the quartic, transvectant systems, syzygies, Hilbert's theorem, Jordan's lemma, and grade; Gordan's theorem (16 pages), giving proof of the theorem and illustration by the cubic and quartic; fundamental systems (16 pages); combinants and rational curves (13 pages); seminvariants and modular invariants (32 pages); and invariants of ternary forms (25 pages). There is added an appendix of ten pages devoted to exercises.

With access to the foregoing books, to Salmon's classic book, and to such recent British works as that by Grace and Young and Elliott's "Algebra of Quantics," the English-speaking student can not complain of having to resort to other languages for a knowledge of this classic branch of modern algebra.

Many readers, including mathematicians and philosophers, will be grateful to Mr. Jourdain for his excellent translation of Cantor's famous memoirs of 1895 and 1897. These were published in the *Mathematische Annalen* under the title, "Beiträge zur Begründung der transfiniten Mengenlehre." The translator's rendering of the title is justified by the content of the memoirs. This content is not likely to be fully intelligible to any but such as have mastered Cantor's earlier works beginning in 1870. The value of the volume is much increased by the translator's Introduction of 82 pages sketching the development of function theory in the course of the last century and by the notes he has appended dealing with the growth of the theory of transfinite numbers since 1897.

Dr. Leib's collection of problems presents a good list under each important theme dealt

with in a first course in the calculus. But few of the problems have been worked out fully and the devising of geometric figures has been left to the student under the guidance of the text he is using or of his instructor, but numerous cautionary and directive explanations are given clearly and concisely, usually at the beginnings of the various problem lists. The answers to typical exercises of each list are given, but a large percentage of the problems are unanswered. Such a collection of exercises ought to make it practicable to teach the elements of the calculus by means of lectures or by means of thin books confined mainly to a presentation of theory.

There are two special reasons why the appearance of Professor Carmichael's beautiful book should be noted in this journal. One is that the subject treated has made a most extraordinary appeal in all scientific times and places. With the exception of geometry, astronomy and logic, hardly any other technically scientific subject has better served to tie together so many centuries, for interest in it probably antedates the school of Pythagoras. The second reason is that a certain long-outstanding problem of Diophantine analysis has recently come to very popular fame by virtue of the extraordinary prize of $25,000 provided by the German mathematician Wollfskehl for its solution. The problem is to prove the so-called Last Theorem of Fermat (1601–1665) stated by him without proof on the margin of a page of his copy of a fragment of the "Arithmetica" of the Greek mathematician Diophantos. The theorem is: *If n is an integer greater than 2 there do not exist integers x, y, z, all different from zero, such that* $x^n + y^n = z^n$. The prize, the offer of which does not expire till September 13, 2007, will be awarded to one who proves that the theorem is not universally true (if it is not) and who at the same time determines all values of n for which it is true. Long before the prize was announced the problem engaged the efforts of great mathematicians and thus led to important developments in the theory of numbers. Since the announcement thousands of the mathematically innocent have assailed the problem. If these innocents could have had access to such a book as Professor Carmichael's where the nature of the problem is explained and the present state of knowledge regarding it is sketched, they might have been deterred from wasting their time and that of others.

The rendering of such a service was not, however, the author's aim. There is scarcely another branch of mathematics in which the results achieved in course of the centuries are so special, fragmentary and isolated. Professor Carmichael's aim was two-fold, namely, to produce for beginners an introduction to Diophantine analysis and to bring its fragmentary and scattered discoveries into organic unity. And he has succeeded admirably. The style is excellent. The content and scope of the book are fairly well indicated by the titles and lengths of its six chapters: Introduction, rational triangles, the method of infinite descent (22 pages); problems involving a multiplicative domain (30 pages); equations of third degree (20 pages); equation of fourth degree (10 pages); higher equations, the Fermat problem (17 pages); the method of functional equations (9 pages). The theory thus actually presented and the judiciously selected exercises make the work available for private reading as well as for a short university course in the subject.

Professor Miller's "Historical Introduction to Mathematical Literature" grew out of a course of lectures designed to supplement regular instruction. It thus employs a more or less expansive style and seeks to be "synoptic and inspirational" for such as may not lay claim to much mathematical discipline. It is guided by a highly commendable aim: namely, to conduct the reader to commanding points of view so that he may judge for himself whether the fields he is thus enabled to glimpse invite him to further exploration. The aim is pursued with a notable optimism despite the nation-wide depreciatory utterances of such educational leaders and agitators as Commissioner Snedden and Abraham Flexner. Professor Miller believes that "shameless ignorance" of mathematics "does not represent a

normal condition on the part of those interested in the history of the human race." We are also told that "with our gradual evolution from the state of barbarism the history of war and bloodshed is being slowly replaced by that of political and intellectual movements." From which we infer that that portion of the preface was composed prior to August, 1914.

Believing that history courses for secondary-school teachers should be more largely concerned with modern developments than is their wont, Professor Miller particularly stresses these developments, though the content of his discourse is in very considerable measure drawn also from ancient and medieval times.

The 35 pages of the initial chapter are devoted to sketching the progress made from the beginning of the nineteenth century to the present time in mathematical intelligence, mathematical research, mathematical history and mathematical teaching. In particular the fact is pointed out that the rapid and continuously increasing American mathematical activity during the last twoscore years has placed our country among the leading mathematical countries of the world. If we have not yet produced a mathematician of the very first rank, we can at least claim to have produced men of notable ability and productiveness.

Chapter II. (42 pages) presents a large amount of interesting information respecting types of recent literature, societies, international congresses, periodicals, works of reference, mathematical tables and collected works. In the 51 pages of the third chapter we have a rather meager discussion of definitions of the term mathematics; a historical account of the manner in which the science has acquired its grand divisions and subdivisions; a quite too brief but interesting account of the advent, influence and position of a few "dominant concepts" such as irrational quantities, equation solution, function, group, matrix, domain of rationality; some instructive remarks and historical references respecting mathematical terminology and notation; a short section on errors in mathematical literature; a section, entitled living mathematicians, arguing with feeling and good judgment the importance of devising suitable means for determining "Who is Who" among mathematicians; and a final section treating inadequately, hardly more than touching, the now pressing question of mathematics as an educational subject.

There follow three chapters dealing with "fundamental developments" respectively in arithmetic, in geometry and in algebra. Of these the first (29 pages) opens with Euclid's proof that the number of prime numbers is infinite; explains the Sieve of Eratosthenes; sketches the history and appraises the significance of irrational numbers, giving (doubtless unintentionally) the impression (p. 133) that these numbers admit of only negative definition; treats briefly the fundamental operations of arithmetic, then of notation systems, and closes with a short and excellent account of the Fermat theorem. The next chapter (23 pages) devotes to "fundamental developments in geometry" three sections, one to the Pythagorean theorem, one to the area and volume of the sphere, and one to the triangle. A valuable chapter (22 pages) on algebra is historically rich in its handling of the fundamental theorem of algebra, the notion of determinant, numerical equations, domains of rationality, the beginnings of invariant theory, and the tale of the binomial theorem.

Chapter VII., somewhat oddly entitled "Twenty-five Prominent Deceased Mathematicians," is the largest and most interesting division of Professor Miller's interesting book. It contains a very readable account of the following men selected from among the great mathematicians of the world: Euclid, Archimedes, Apollonius, Diophantus, Vieta, Descartes, Fermat, Newton, Leibniz, Euler, Lagrange, Gauss, Cauchy, Steiner, Abel, Hamilton, Galois, Sylvester, Weierstrass, Cayley, Hermite, Kronecker, Cremona, Lie, Poincaré.

The book closes with a list, accompanied with brief characterizations, of a large number of bibliographies, reference works, and books on the history, and the teaching and philosophy of mathematics.

Cassius J. Keyser

Columbia University

The Mental Life of Monkeys and Apes: A Study of Ideational Behavior. By ROBERT M. YERKES. New York, 1916. Pp. 145.

This monograph reports the results of admirable experiments on two monkeys and an orang-utan, first, by the multiple-choice method of Yerkes, and second, by various forms of the mechanical-adaptation method. It also presents a plan for a research institute for the study of the primates.

The multiple-choice method is a means of diagnosing and measuring an animal's ability to respond correctly to relations of spatial order, such as *middle door of those open*, or *right-hand door of those open*, regardless of the number of doors that are open or which doors (of the entire nine possible to be open) they are. Food was used as a reward for entering the right door, and, irregularly, detention in a box as a punishment for entering the wrong door.

The first problem was to learn to enter at once the first door at the left end of whatever doors were open. The following summary for one monkey will give an idea of the sort of facts obtained. In the course of 150 trials the per cent. of successes rose from 30 to 90, for the ten selections of doors open that were employed. In a test with one trial each of ten still different selections of doors the number of successes was 6. The monkey did not seem to learn by a "free idea" of "*door at left end*"; for each selection of doors seemed to be responded to by itself. 8 as the response to 8–9, 6 as the response to 6–7–8, 4 as the response to 4–5–6–7–8, 7 as the response to 7–8–9 and 5 as the response to 5–6–7 were apparently learned at a time when 1 as a response to 1–2–3, 3 as a response to 3–4–5–6–7 and 2 as a response to 2–3–4–5–6, were not. There was no sudden elimination of wrong responses. "Stupid" responses appeared in connection with the general behavior in the test.

As a result of four such series of experiments with one monkey and three with another, Yerkes concludes that "the *Pithecus* monkeys yielded relatively abundant evidence of ideation but with Thorndike I must agree that of 'free ideas' there is scanty evidence, or rather, I should prefer to say, that although ideas seem to be in play frequently, they are rather concrete and definitely attached than 'free.' Neither in my sustained multiple-choice experiments nor from my supplementary tests did I obtain convincing indications of reasoning. What Hobhouse has called articulate ideas I believe to appear infrequently in these animals. But on the whole, I believe that the general conclusions of previous experimental observers have done no injustice to the ideational ability of monkeys."

The orang-utan seemed to get "an idea of" *left-end-door of those open* and use it to guide his responses. He did not, however, apparently get the idea of *next-to-the-right-end-door* in 1,380 trials. Various phases of his behavior, however, convinced Yerkes that he was responding to ideas or representations of experience.

In the miscellaneous tests the orang-utan showed great pertinacity and initiative. On the whole "the orang-utan is capable of expressing free ideas in considerable number and of using them in ways highly indicative of thought-processes, possibly even of the rational order. But contrasted with that of man, the ideational life of the orang-utan seems poverty-stricken."

The experiments with the monkeys and the ape are described with the author's customary care and will be of service in many ways to future workers in this field. For example, they bear directly on the Smith-Watson-Carr doctrine that frequency of connection, irrespective of the consequences of the connection to the animal, is adequate to account for learning. Cases abound in the records where a certain wrong door is in the first few trials chosen far oftener than the right door and yet eventually is never chosen. The multiple-choice experiments should be widely used in studies of both animal and human learning.

The last division of the monograph presents Yerkes' proposal for the provision of a special institute for studying the monkeys and apes. Porto Rico and Southern California are suggested as satisfactory localities. The indirect value of such an institute for human

betterment is emphasized as well as its direct value in the advancement of knowledge, and strong claims are made for its support.

It certainly is the case that animal psychology in this country has, in the past decade, done very solid and instructive work with very little financial support from universities or research funds. The experiments here reported represent a gift of the time of one man of science and a gift of material resources from another. They are typical of the scientific devotion and self help which the public can profitably reward by any means in its power, and which any individual honors himself by supporting.

Edward L. Thorndike
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Columbia University

RETROGRESSION IN AMERICAN LONGEVITY AT ADVANCED AGES

It is generally suspected among a limited group of scientific men that although we seem to be improving in matters of health we are doing so in spite of adverse conditions at the more advanced ages.

We have certainly improved on the whole, for the area in the United States from which acceptable records in mortality statistics are received annually (the registration area) has doubled in the number of states included, within the past decade (1900–1910), although it is still no more than half of the total number of the states of the Union, to the shame of such great states as Illinois, Iowa, Kansas, Nebraska, etc. That mortality conditions have improved in the neighborhood of the age of birth and in fact, at all the earlier ages, is so well established that it needs no comment. Also, the general death rate in this country has decreased more in the past decade (2.6) than in the previous two decades taken together (2.2).

But all this improvement is too deceiving; it covers up the fact that in some respects we are worse off now than we were twenty years or more ago. Stated concretely we expect to show in this paper that individuals between the ages of about 50 and 75 do not, on the average, live as long now as they did twenty years ago; and the extent of this retrogression is increasing. We shall refer to this period or interval of ages as the Period of Retrogression.

We hope to point out also slight indications of tendencies to "come back" at the still more advanced ages, say from 75 on. That the individuals at these extreme ages are "coming back" seems pretty firmly indicated by the results of this investigation, but not only is the "come back" small but it is also manifested at ages where statistical data are faulty; hence, we recommend that these indications be held in abeyance until they are more clearly verified by other investigations of similar nature.

The English statistician and actuary, Mr. George King, has explained a short method of constructing abridged mortality tables wherein only representative portions of the tables and the corresponding death rates and expectations of life are given. We have utilized this method to construct six abridged mortality tables based upon the mortality statistics of each of the sexes, and for the three single years 1890, 1900, and 1910. The year 1880 was not included because the population data and mortality statistics for that year which were reliable do not cover exactly the same area. The mortality statistics of all years previous to 1880 are worthless for our purpose. The essential purpose of this paper is to compare and discuss the results obtained through the construction of these mortality tables.

The fact that each mortality table is constructed from data covering but a single year absolutely prohibits the use of such tables except to point out general conclusions such as are indicated in this paper. Our attitude in this matter should not be forgotten.

As the explanation of the method of construction of the tables is technical and has no special bearing upon the interpretation of the final results, we shall merely refer the reader who desires further information to Mr. King's explanation—which, however, will bear much simplification—in the Registrar General's report for 1914.

The statistical data for the year 1890 com-

prise the population and deaths of the nine registration states of that year: Connecticut, Delaware, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and the District of Columbia. The statistics of the years 1900 and 1910 which were used in this investigation comprise those of the same states enumerated above, except Delaware, and of the states Indiana, Maine and Michigan.

The mortality tables were completed at the extreme and relatively unimportant ages not covered by reliable data, in the rather arbitrary manner discussed by Mr. King.

The abridged mortality tables are given here for visual comparison, but our discussion will be directed solely to the death rates and expectations of life given later.

MORTALITY TABLES

	1890		1900		1910	
Ages	Males	Females	Males	Females	Males	Females
12	100,000	100,000	100,000	100,000	100,000	100,000
17	98,026	97,715	98,390	98,182	98,537	98,678
22	94,558	94,613	95,596	95,466	96,281	96,665
27	90,219	90,793	92,115	92,066	93,487	94,089
32	85,655	86,559	88,414	88,379	90,344	91,220
37	80,876	82,122	84,450	84,594	86,618	88,036
42	75,777	77,484	80,108	80,625	82,281	84,485
47	70,309	72,670	75,247	76,289	77,246	80,445
52	64,259	67,318	69,998	71,206	71,394	75,532
57	57,290	61,084	63,556	64,932	64,260	69,204
62	49,359	52,181	55,178	57,292	55,255	61,098
67	40,571	43,990	45,167	48,036	44,707	50,974
72	31,000	34,582	33,670	36,844	32,651	38,674
77	20,826	24,192	21,806	24,707	21,358	25,362
82	11,308	14,022	11,151	13,372	11,643	13,677
87	4,579	6,244	4,013	5,240	4,212	5,678
92	1,388	1,976	898	1,347	1,068	1,671
97	339	464	108	198	227	316
102	68	84	6	14	40	34
107	11	12	0	0	6	2
	0	1			0	0

It is to be noticed that the ages in the neighborhood of the age of birth are ignored. This is practically necessary in the use of such short methods, considering the great variations in death rates at the ages of this period. However, examination of various mortality tables constructed upon mortality conditions in the United States will reveal little difference between the expectation of life at age twelve and that at the age of birth. Thus, the expectation of life at age twelve is a fair estimate of the average length of the whole of American life, especially when used for purposes of comparison of two or more sets of mortality conditions.

The abridged list of death rates and corresponding differences are as follows:

DEATH RATES PER 100,000

Males

Ages	1890	Diff.	1900	Diff.	1910
12	331	— 55	276	— 39	237
17	546	— 64	482	— 89	393
22	864	— 165	699	— 141	558
27	1,015	— 230	785	— 156	629
32	1,065	— 196	869	— 98	771
37	1,260	— 273	987	— 40	947
42	1,358	— 204	1,154	— 7	1,147
47	1,696	— 313	1,383	+ 50	1,433
52	1,961	— 306	1,655	+ 152	1,807
57	2,757	— 283	2,474	+ 99	2,573
62	3,277	+ 53	3,330	+ 311	3,641
67	4,781	+ 159	4,940	+ 120	5,060
72	6,172	+ 874	7,046	+ 597	7,643
77	10,075	+ 475	10,550	+ 738	11,288
82	13,893	+1,967	15,860	— 628	15,232
87	20,324	+2,344	22,668	+ 25	22,693
92	23,384	+7,475	30,859	—5,332	25,527

Females

Ages	1890	Diff.	1900	Diff.	1910
12	382	— 70	292	— 69	223
17	574	— 92	482	— 135	347
22	745	— 77	668	— 165	503
27	924	— 133	791	— 206	585
32	987	— 143	844	— 176	668
37	1,136	— 217	919	— 146	773
42	1,195	— 169	1,026	— 125	901
47	1,417	— 181	1,236	— 123	1,113
52	1,705	— 97	1,608	— 104	1,504
57	2,281	— 84	2,197	— 65	2,132
62	2,846	+ 118	2,964	+ 72	3,036
67	4,207	+ 138	4,345	+ 145	4,490
72	5,637	+ 928	6,565	+ 305	6,870
77	8,988	+ 663	9,651	+ 437	10,088
82	12,610	+1,106	13,716	+ 464	14,180
87	18,496	+2,367	20,863	— 867	19,996
92	23,437	+5,049	28,386	+4,482	32,868

In the table of death rates given above, attention is called not so much to the absolute values and their differences—for the results lack graduation—but rather to the trend of mortality conditions as indicated by them. This trend among both the males and females is unquestionably forward at all ages below 60, except in the decade 1900–1910, in which the advance among the males is terminated at

about age 45. We might go farther and say that for this same decade the males did not advance as much at the ages at which they did advance as they did in the previous decade. On the other hand, the females maintained or even excelled their record of 1890–1900 in the decade 1900–1910.

The most important feature of the table of death rates is the group or period of ages at which both males and females have retrogressed. This retrogression is significant in value wherever indicated, and that it is not due to faulty statistics or errors is clearly shown by the fact that it appears *in both decades in both sexes.* Further, the retrogression is not spasmodic, but continues firmly from about age 60 on to the end of the table.

EXPECTATIONS OF LIFE

Males

Ages	1890	Diff.	1900	Diff.	1910
12	46.30	+2.19	48.49	+ .59	49.08
17	42.18	+2.06	44.24	+ .53	44.77
22	38.63	+1.82	40.45	+ .30	40.75
27	35.37	+1.52	36.89	0	36.89
32	32.12	+1.21	33.33	– .24	33.09
37	28.86	+ .91	29.77	– .37	29.40
42	25.64	+ .60	26.24	– .42	25.82
47	22.43	+ .35	22.78	– .45	22.33
52	19.30	– .01	19.29	– .34	18.95
57	16.34	– .35	15.99	– .29	15.70
62	13.56	– .54	13.02	– .10	12.92
67	10.94	– .60	10.34	+ .02	10.36
72	8.54	– .54	8.00	+ .26	8.26
77	6.49	– .49	6.00	+ .33	6.33
82	4.51	– .07	4.44	+ .15	4.59
87	3.73	– .48	3.25	+ .34	3.59
92	2.79	– .51	2.28	+ .76	3.04

Females

Ages	1890	Diff.	1900	Diff.	1910
12	47.90	+1.56	49.46	+1.83	51.29
17	43.96	+1.36	45.32	+1.62	46.94
22	40.31	+1.23	41.54	+1.32	42.86
27	36.90	+1.08	37.98	+ .98	38.96
32	33.58	+ .88	34.46	+ .65	35.11
37	30.26	+ .63	30.89	+ .40	31.29
42	26.92	+ .37	27.29	+ .21	27.50
47	23.54	+ .15	23.69	+ .06	23.75
52	20.21	– .01	20.20	– .07	20.13
57	17.00	– .10	16.90	– .17	16.73
62	14.47	– .66	13.81	– .21	13.60
67	11.69	– .71	10.98	– .19	10.79
72	9.18	– .72	8.46	– .05	8.41
77	7.04	– .65	6.39	+ .13	6.52
82	5.37	– .62	4.75	+ .28	5.03
87	4.14	– .61	3.53	+ .33	3.86
92	3.33	– .76	2.56	+ .36	2.92

There are a few widely varying values at the terminal ages, but, as mentioned above, the statistics at these ages are so faulty that little or no interpretation is possible.

Summarizing the results indicated by the table of death rates, mortality conditions seem to have been improved at ages below sixty during the two decades 1890–1900 and 1900–1910 among both the males and the females, steadily so among the females but not so much so among the males. At ages sixty and above, both males and females seem to have retrogressed, particularly the males whose period of retrogression during the decade 1900–1910 began as far back as age 45. This period of retrogression among death rates for both sexes continues steadily toward the last ages of human life.

As indicated in the table of expectations of life given above, the average future life time of males at age twelve seems to have lengthened 2.19 years in the decade 1890–1900 and only .59 of a year in the decade 1900–1910, or 2.78 years in both decades. The gain of only .59 is rather difficult to explain, for even the general death rate suffered a relapse in 1910, and no one seems to know exactly why. It is possible that the fact that the period of retrogression encroached upon the earlier ages might offer at least a partial explanation. The period of retrogression among the expectations of life of the males is seen to begin about age fifty in the decade 1890–1900 and about age thirty in the decade 1900–1910.

That the initial ages of the period of retrogression in both decades precede the corresponding ages in the table of death rates from 10 to 15 years is what might be expected and is really quite important in that it emphasizes the fact that a retrogression in death rates at any period of ages will affect the expectation of life of *all* those living at any earlier ages. The two initial ages, fifty and thirty, mentioned above, differ from earlier ages only in the fact that these are the first ages at which the effect of retrogression at the advanced ages outweighs the effect of improvement at the earlier ages.

The amount of retrogression in the expectation of life of the males rarely exceeds half of a year, but the mere fact that individuals at ages above fifty do not live as long now as they did several decades ago is of tremendous significance. If this period or retrogression could be made to vanish, so much more would the expectation of life at the earlier ages be increased. It would be serious enough if no advance were registered in this period; an actual retrogression amounts to a calamity.

It is very remarkable that the period of retrogression of the males in the decade 1900–1910 ends about age sixty-five and from that age on we notice a tendency to "come back," a tendency not found in the decade 1890–1900. The value of this "come back" is small, it is true, but the values give no indications of uncertainty by interposing occasionally a negative value (a retrogression). Whether this period of advance at the most extreme ages actually exists or not, we shall not presume to say, but the above figures are highly suggestive.

The period of retrogression among the expectations of life of the females also begins about age fifty, but there is quite a difference between the two decades considered. In the decade 1900–1910 the females seem to have overcome to a great extent the retrogression registered in the decade 1890–1900; this fact is not true of the males. Moreover, this period is now restricted to only about twenty years, whereas before it seemed to extend firmly to the end of the table.

Here again, we see evidences of an effort to "come back" appearing at the extreme ages. The fact that this period of "come back" appears among the expectations of life of the females in the same decade (1900–1910) as it does among the males adds strength to the probability of its actual existence.

The casual reader may have wondered how the period of retrogression among the death rates could extend to the end of the table while that of the corresponding expectations of life could end at some age such as 75. This is perfectly possible, for in obtaining the expectation of life at any age we divide the total number of years lived, by the population at that age, and this total number of years may be lessened without decreasing the expectation of life if the population at the given age is also lessened in the proper proportion.

In this paper we have pointed out a great field for work; we have pointed out the exact location of a serious problem. It still remains for others to diagnose the trouble, and that task might well be left to those familiar with the diseases operative at the ages covered by this period of retrogression. However, we dare suggest that far the greater part of the trouble is due to a peculiar state of indifference and ignorance in regard to the ordinary laws of nature, and therefore can be overcome best by a systematic plan of education along lines of elementary hygiene.

Every one knows that few individuals between the ages of thirty and sixty take any constructive forethought for their physical welfare; few carry out any definite plans for regular daily exercise or proper breathing of fresh air. Fewer still have even a fair conception of their own physical make-up or their condition at any particular time; this fact is due likely both to lack of time and to reluctance to face the truth.

One of the best ways to arouse interest in practical hygiene would be through the organization of a National Health League which would hope ultimately to have a representative organization in every large community. It should be the duty of such a body to encourage right living among its members and all individuals associated with them. This work should be supplemented by a systematic and regular program of study and discussion. For local organizations made up of individuals who insist they are too busy to make a personal study of the subject, practical lectures could be arranged at regular intervals, calculated to keep interest aroused. The lecturers could be obtained among broadminded and altruistic physicians or the faculty of the state university. The central organization, whether state or national could employ a part of its time and energy in no better way than in providing

a complete corps of efficient lecturers who could answer the call to some local organization.

There are many individuals who are looking for a field in which they can utilize their executive powers in a worthy way. There are many wealthy people who are ready and even anxious to donate funds to a worthy cause. We believe a no more worthy cause exists than the one just suggested.

Much work has already been accomplished by organization such as the Y. M. C. A. to encourage right living among young men, but little of it touches the group of busy individuals who are the victims as well as the causes of the Period of Retrogression.

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SPECIAL ARTICLES

A METHOD OF PLOTTING THE INFLECTIONS OF THE VOICE

Some time ago, while the writer was engaged in the study of the "tones" of certain oriental languages, it became desirable to represent visually the tonal movements or figures executed by the voice in actual speech. Records of native speech were taken by the Rousselot apparatus, and the wave-lengths in each tracing were measured throughout, resulting in a series of numbers for each utterance—which series we may for the moment suppose as included within the compass of two octaves, from 10 to 40 of our scheme.

In default of any record of previous attempts of this kind, the following scheme was first tried as the most obvious and simple. Beginning at the top, the unit lines of the coordinate paper were numbered in succession downward from 10 to 40. Then beginning at the left-hand margin the measured numbers from the record were plotted in order, each upon its numbered line, but each advanced beyond its predecessor by a constant interval chosen after experiment as best suited to bring out the features of the voice-inflection. A continuous line drawn through the series of plotted points would then represent the movement of voice as regards pitch. Finally the whole was brought into relation with concert pitch by measuring the wave-length of the record of a C-fork and marking its place among the numbered lines, and computing the positions of the other notes of the scale according to the well-known ratios of the diatonic scale.

The results seemed convincing; but a study of them revealed a certain distortion of vertical values similar in kind to the horizontal distortion of Mercator's maps. This was due to the fact that the number-intervals were equally spaced, whereas to our thought and visual imagination the semitone intervals are equal. The first step toward remedying the difficulty was obvious and easy. The letters of the twelve semitones took the places of the integers on the unit-lines of the chart. The next step—to find the new places of these integers—was not so easy. After some fumbling and groping the following points became clear.

1. Each semitone of the series brings with it to its new place the same numerical value which it had in its former position as a definite term of a geometrical progression of twenty-four terms between 10 and 40, with $\sqrt[2]{2}$ for the common ratio. In Table I. below are given these values for the upper octave. Those for the lower octave are simply twice these. These numbers were entered on the chart against their respective semitones.

2. The integral numbers must next be assigned to their proper stations within this decimal series. Indeed 10, 20 and 40 already appear in that series, and so are assigned to position; while 15 and 30 are so close to semitone positions as to be practically coincident with them. A rough determination of the other positions might be made by the method of proportional parts, but the only real determination is by solving the equation of the geometrical progression just described. That equation is $y = a^x$, in which y and x are variables, and a is constant, namely the common ratio $\sqrt[12]{2}$. The values of y are the integral numbers from 10 to 40. By applying these values in succession to the equation, the corresponding values of x are obtained, that is the

vertical distance from line 10 to the level of each integer. These ordinates are given in Table II. below.

Another element of distortion, though very slight, was found in the assumption of equal spacing for the horizontal intervals between successive points in the plot. The spaces *ought* to vary somewhat according to the levels of pitch. It was, however, some time before it became clear that the single measurement determined the position of the point on *both* coordinates—on the vertical one as pitch, and on the horizontal one as time-elapsed between successive wave-crests in the record.

So amended, the scheme seems perfect. Nevertheless a suggestion or two may save much time and trouble to one who may have occasion to use it.

It is neither necessary nor desirable to measure separately every wave-length of the record. It is quite as well to measure them in groups of five together and take the average for plotting, if only one measure separately the very first wave and the last, so as to make sure of the pitch at those points. Similarly the intervals for the horizontal spacing need not be the very ones indicated by the measured numbers, but rather some constant fraction of them, such as will better bring out the features of the curve.

All the numbers concerned in the scheme are merely ratios setting forth the relationships between the various elements of it within the compass of two octaves of pitch, which is quite sufficient to cover the range of any voice in ordinary speech. The scheme may therefore be used just as it stands if the measurements do not exceed its limits. If they do, the whole system may be raised an octave by the simple device of dividing the integral numbers throughout by 2, or lowered an octave by multiplying them by 2. Or it may be raised a fourth by multiplying them by 0.7, or lowered a fourth by multiplying them by 1.5—taking pains however in these last cases to shift the semitone letters correspondingly.

Since the semitone intervals are all equal, the C which represents concert pitch may be placed anywhere in the field where its measured wave-length indicates. All the other semitone letters then will take their places at the same constant distances as in the scheme described.

TABLE I

Ratios of the Tempered Scale

C	10
B	10.60
A♯	11.23
A	11.89
G♯	12.60
G	13.35
F♯	14.14
F	14.98
E	15.87
D♯	16.81
D	17.81
C♯	18.87
C	20

TABLE II

Ordinates of the Number Series

Number	Distance	Number	Distance
10	000	26	16.54
11	165	27	17.19
12	316	28	17.82
13	454	29	18.43
14	582	30	19.02
15	702	31	19.58
16	814	32	20.14
17	918	33	20.67
18	1,017	34	21.19
19	1,111	35	21.69
20	1,200	36	22.17
21	1,284	37	22.65
22	1,365	38	23.11
23	1,442	39	23.56
24	1,515	40	24.00
25	1,586		

CORNELIUS BEACH BRADLEY
UNIVERSITY OF CALIFORNIA

SOCIETIES AND ACADEMIES

THE BIOLOGICAL SOCIETY OF WASHINGTON

THE 557th regular meeting of the society was held in the Assembly Hall of the Cosmos Club, Saturday, May 20, 1916, called to order by President Hay at 8 P.M., with 30 persons present.

On recommendation of the council, James L. Peters was elected to active membership.

The president announced that the council of the society had voted to adopt the custom of medical societies and of many other scientific societies limiting the members to speak but once during the

discussion of papers and of asking the original speaker to answer all questions at the end of the discussion and to close the same.

Under the heading of brief notes and exhibition of specimens, Dr. Howard E. Ames referred again to the dorsally placed mammæ of the coypu (*Myocastor coypu*) and exhibited photographs of a female coypu in the collection of the Philadelphia Zoological Society showing the mammæ so placed.

The first paper of the regular program was by A. T. Speare, "Some Fungi that Kill Insects." Mr. Speare spoke briefly of certain experiments that were conducted in Europe about 1885, in which place the "green muscardine" fungus was used in a practical way to combat the cockchafer of wheat. Reference was also made to similar work that has recently been conducted in Florida and Trinidad, B. W. I. The writer spoke also of the present status of the chinch-bug disease and of the brown-tailed moth disease. In regard to the latter he spoke in detail of the methods employed in spreading this disease in the field. At the end of the paper he exhibited lantern slides illustrating various types of entomogenous fungi, some of which were collected by him in the Hawaiian Islands. Mr. Speare's communication was discussed by General Wilcox and by Dr. Howard.

The second paper was by L. O. Howard: "The Possible Use of *Lachnosterna* Larvæ as a Food Supply." Dr. Howard briefly referred to the prejudice against insects as food, and gave an account of his experiments recently undertaken with white grubs sent in from Wisconsin. They were sterilized, thoroughly washed, the contents of the alimentary canal removed, and were then served as a salad and in a broth. They were eaten by several members of the Bureau of Entomology and by Mr. Vernon Bailey of the Bureau of the Biological Survey and were pronounced distinctly edible. The speaker urged further experimentation with abundant species of insects as to their food value. Dr. Howard's communication was discussed by the chair, Mr. W. E. Safford, General Wilcox and Medical Inspector Ames.

The last paper was by W. E. Safford: "Agriculture in Pre-Columbian America." Mr. Safford described the various plants used by the early inhabitants of America, particularly those of Mexico, Central and South America, the manner of their use and preparation, and called attention to those employed at the present day and which have been adopted by civilized man. The prominent part which these plants played in the life of the pre-Columbian inhabitants is shown in ceremonial objects, earthenware products, etc., ornamented by designs based on these plants and in some cases by molds of parts of plants. Mr. Safford's communication was illustrated by numerous lantern-slide views of the plants under consideration and of many objects bearing plant designs. It was discussed by the chair, General Wilcox and Professor E. O. Wooton.

M. W. Lyon, Jr.,
Recording Secretary

ANTHROPOLOGICAL SOCIETY OF WASHINGTON

At the 499th regular and 37th annual meeting of the Anthropological Society of Washington, on April 18, Dr. John R. Swanton, president of the society, read a paper on "The Influence of Inheritance on Human Culture."

The speaker distinguished between the physical and mental traits which one inherits in his own person, and the store of ideas and things which have been passed down to him by previous generations. The environment into which one is born is of two kinds, the environment unaffected by man, and the environment as modified by man; and the advancement of a tribe depends on the amount of environment it is able to grasp and transmit. In this way a mental and material capital is laid up which enables further progress to be taken much more easily. Nevertheless, all of this world capital is not good, since false ideas and injurious institutions may be transmitted as well as true principles and beneficent institutions. One of the most pernicious of these institutions is that which permits monopolization of ideas and things by limited classes. A general diffusion of knowledge and improvement of the means of distributing it has largely destroyed monopoly in ideas, but monopoly in property still persists. The cure for this condition is to be found, the speaker believed, either in binding together use and ownership in such a manner that they can not be separated, or in vesting ownership in an immortal body such as the state and allowing use to individuals during their lives.

The following officers were elected for the ensuing year: President, Dr. John R. Swanton (reelected); Vice-president, Mr. William H. Babcock; Secretary, Miss Frances Densmore; Treasurer, Mr. J. N. B. Hewitt (reelected); Councillors, Dr. Truman Michelson, Mr. Neil M. Judd, Mr. Francis La Flesche, Dr. C. L. G. Anderson, and Dr. Edwin L. Morgan.

Frances Densmore,
Secretary